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STUDIES IN WESTERN YELLOW PINE NURSERY PRACTICE [1]

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INTRODUCTION

In 1912 and 1913, when nursery experiments were started under direction of the then "Priest River" Forest Experiment Station, at Priest River, Idaho, and elsewhere, western yellow pine (*Pinus ponderosa*) was one of the principal species being planted on a large scale in the northern Rocky Mountain region and millions of plants were being raised each year in the Forest Service nurseries; but comparatively little careful study had been made to determine the best methods of handling this stock in the nursery to obtain good quality at a minimum cost. The experience of the years following 1909, when the nursery work was first undertaken on a large scale, demonstrated beyond question the need of experimentation in order to produce a better and more uniform quality of stock and to avoid the delays, uncertainties, and losses due to lack of exact information.

The investigative work undertaken at this time was limited to those phases of the western yellow pine nursery practice most suitable for study at a small experimental nursery with limited facilities and at a considerable distance from the large nurseries operating on a commercial scale. These phases were: (1) Depth of covering seed in the seed bed; (2) methods of sowing seed in the seed bed; (3) degree of shade to use on the seed bed; (4) amount of water to use on the seed bed, with or without cultivation.

Such phases as the proper amount of seed to sow, the best season to sow, the need for fertilizing the soil, development of a good root system, and methods and season of transplanting, could at that time be studied better at the larger nurseries, either because of the large scale on which it was necessary to conduct the investigations or because the problems were more or less local and could best be solved at the nursery where the results were to be applied.

While the four phases selected for study are to a certain extent interrelated with climatic and soil conditions, these conditions at the field station in northern Idaho sufficiently resemble those at the Savenac Nursery in northwestern Montana to permit putting into practice there the results obtained at the Idaho station. The mean monthly temperatures for the growing season at Savenac average only one or two degrees lower than those at Priest River. Percentage of sunshine and wind velocity are probably somewhat greater at Savenac, but the same general regional climate prevails at both places.

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All studies were conducted at the Priest River field station, with the exception of duplicate experiments in the study of the depth of cover begun at the Savenac and Boulder nurseries in 1912 and at the Trapper Creek nursery in 1914, under the direction of the experiment station.

The 1912 depth of cover bed at Priest River was located at the Benton Flat nursery, a dry flat with a sandy loam soil and thin sandy subsoil. The 1913 studies of depth of cover, and all studies on the other three phases, were located in a group of sixteen 4 by 12 foot beds known as the Meadow nursery. These beds were on a gentle southerly slope just above a flat meadow near Benton Creek. They had about a 10 per cent gradient, and were terraced to make their surfaces level. The natural soil was a fine silt loam 12 to 18 inches deep with a reddish color and a marked tendency to become compact or caked on the surface. It was underlaid by a light gray, claylike silt subsoil so compact and hard that water penetrated very slowly. To overcome the heavy nature of the soil, sharp granitic sand was mixed with the top 6 inches of each bed, rendering the soil loose and loamy and largely overcoming the tendency to pack on the surface.

In all of the experiments included in this series, counts of germination and of loss were made approximately once a week throughout the germinating period of the first season in the seed bed. A survival count was made at the end of the season to check the totals which had been carried forward. Each seedling, as soon as its germination was noted, was marked by sticking a toothpick in the ground just north of it. Toothpicks were colored to indicate the month in which germination occurred. Dead seedlings and the corresponding toothpicks were removed at each weekly count and the cause of death noted. Damping-off was found to be the most prevalent cause of death of first-year seedlings.

In the fall or following spring, at the time of removing the seedlings from the seed beds, measurements and weights were obtained of representative plants to show relative development under different conditions. From one to five seedlings, depending on the number available, and representing as nearly as possible the average development of each lot of plants, were preserved for future record. Photographs were made of these specimen plants in the winter of 1916–17 to illustrate differences in development due to varying treatment in the seed beds.

DEPTH OF COVERING IN SEED BED

SUMMARY

Depth of covering layer has a direct effect on the temperature and moisture of the soil in contact with the seed, upon the amount of mechanical obstruction to the growth of the stem toward the surface, and on the favorable conditions for the development of injurious fungi as well as the vigor and resistance of the plants to fungus attack. It is because of these effects that variations in depth cause differences in germination and survival of seedlings.

In all of the experiments the shallower covers very uniformly show a more rapid germination, a larger total germination, a smaller loss

from damping off and other causes, and a better development of the plants at the end of the season, when compared with the deeper cover. The contrasts are so marked that the use of the shallower cover can be unhesitatingly recommended for use with western yellow pine in all nurseries in this region, at least where artificial watering is possible. The best showing was, on the whole, made by the ¼-inch and ⅜-inch depths. A cover varying between these two, with an average of $\frac{5}{16}$ inch, should be adopted as standard and be adhered to as closely as equipment and facilities will permit, in order to secure greatest economy of seed and space in raising desirable plants.

While it may be difficult to secure and maintain an exactly uniform and minutely regulated depth of cover, owing to mechanical difficulties in applying the cover and because of the washing of surface particles in sprinkling the beds, it has been found possible, by the development (at the Savenac nursery) of a special machine for covering, and by care in watering, to keep variations usually within ⅛ inch and never more than ¼ inch. This makes it feasible to regulate the depth of cover to a range which can be maintained in large scale practice and one within which best results in germination and survival may be obtained.

PROCEDURE

In the spring of 1912, western yellow pine seed, collected on the Bitterroot National Forest in 1911, was sown in the Benton Flat nursery and at the Savenac and Boulder nurseries. Depths of ½ inch and ¾ inch were used, and seed was sown in plots 2 feet square, each containing 500 seeds. Counts were made once a week and seedlings were pulled as counted, thus restricting the record to germination alone.

In 1913 the work was carried out with greater completeness. One bed in the Meadow nursery was thoroughly spaded and worked over until in a good condition for sowing. The bed was then divided by wood strips into two series of six plots each for use with six different depths of cover. In one series the plots were 2 feet square for broadcast sowing, and in the other they were 1 by 4 feet for drill sowing. Thus by duplicating the different depths of cover with the two methods of sowing it was possible to make a combined study of depth and method of sowing in the same bed so as to bring out facts in regard to each phase as well as their relation to each other.

Fresh western yellow pine seed was used. It was collected and extracted at the experiment station the previous fall (1912). Sowing was done June 6, the comparatively late sowing being due partly to delay in getting the new nursery in shape for sowing and partly to the fact that the season of 1913 was from three to four weeks later than the average. About 375 seeds to the square foot were sown, or an amount of seed sufficient to produce an estimated stand of 200 seedlings in each drill, or 200 to the square foot, on the basis of the greenhouse figures. The seed used for each plot was accurately weighed to within a limit of error of 4 seeds or 1 per cent of the good seeds sown, the same weight being used for all plots. Seed was sown as uniformly as possible. The drills were 3 inches apart, 4 drills to a plot, lengthwise.

One plot in each of the two series was covered to one of the following depths: ¼ inch, ⅜ inch, ½ inch, ⅝ inch, ¾ inch, and 1 inch. Clean sharp sand, dug from the sterile subsoil at Benton Flat, was used for covering. After the seed was sown and lightly pressed into the surface several toothpicks were inserted in each plot so that their points projected above the surface to a height exactly equal to the depth of cover desired. The sand was then put on and smoothed off level with the tops of the toothpicks. The lath partitions between plots prevented sand from washing from the plots with deep cover to those with shallower cover.

For want of definite knowledge as to shading requirements, the bed was given one-half shade from the time of sowing to the end of the season.

Water was applied to the bed by means of a hose and fine spray nozzle toward the close of each day during the dry period, except immediately after rains, in a moderate quantity sufficient to keep the upper soil layers moist enough for good growth.

Counts of germination and loss were made once a week, and a final survival count was made October 4, using the colored toothpick method.

In the spring of 1914 the seedlings were removed for transplanting and 50 representative seedlings were mechanically selected for measurement by taking every third, fourth, or fifth plant, depending on the total number in the plot. Figures were obtained on the following points: Length of root in inches, length of stem in inches, weight of 50 tops (fresh and surface dried) in grams. Typical specimens were pressed, and those in the broadcast series were photographed, in February, 1917.

The rest of the seedlings were transplanted at the Benton Flat nursery in the spring of 1914, using a standard "Yale" board. Survival records of transplants were obtained in the fall of 1915, together with measurements of the height and diameter at the ground line of every tenth plant.

One bed sown at the Trapper Creek nursery on the Bitterroot National Forest May 27, 1914, contained 4 plots, each 1 by 4 feet, each plot containing about 600 seeds. One plot was covered to each of the following depths: ¼ inch, ⅜ inch, ½ inch, and ⅝ inch. Seed was sown in drills 3 inches apart, 4 drills per plot, lengthwise. Counts of germination and survival were made June 15, July 1, 15, and 22, and again October 1. Owing to the conditions at Trapper Creek, it was not possible to control this experiment as carefully or have as complete records as for the 1913 experiment at Priest River. The value of this experiment lies chiefly in confirming, in a general way, the Priest River results, and in throwing an interesting sidelight upon the effect of different climatic conditions and methods of irrigation on the optimum depth of cover for yellow pine.

DATA

The germination figures obtained in the 1913 series at the three nurseries—Priest River, Savenac, and Boulder—are summarized in Table I.

TABLE I.—*Germination percentage under different depths of cover, 1912*

Depth of cover	Comparison of nurseries			
	Savanac	Priest River	Boulder	Average
	Per cent	*Per cent*	*Per cent*	*Per cent*
½ inch	50.6	41.4	31.8	41.0
¾ inch	48.6	40.8	27.2	38.9

The differences in these figures for the different nurseries may be partly explained by the fact that sowing was done May 1 at Savenac, May 15 at Priest River, and June 5 at Boulder, because of differences in the beginning of the growing season and the time when it was possible to do the sowing. Climatic differences at the three places are indicated in Table II.

TABLE II.—*Comparison of temperatures and precipitation at nurseries, 1912*

Nursery	Monthly mean temperature		Mean maximum temperature		Precipitation	
	May	June	May	June	May	June
	° *F.*	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*
Priest River	51.7	60.5	80	97	2.68	2.14
Savenac	50.6	59.0	83	97	2.33	1.12
Boulder	46.2	57.4	75	90	4.03	1.32

The temperature figures furnish one evident reason why germination at Boulder was lowest. The higher mean maximum air temperature at Savenac was probably one of the contributing factors in producing greatest germination at that place, when combined with the advantage of early sowing.

While the differences between germination at the two depths are quite small, the fact that they are consistently in favor of the shallower depth of ½ inch at all three places and under different conditions is excellent evidence, when taken in connection with similar evidence from later experiments, to show that ½ inch is a better depth than ¾ inch for covering yellow pine seed.

The germination figures obtained in the 1913 study at Priest River are shown graphically in Figures 1 and 2, where the effects of the different depths of cover and of the two methods of sowing are compared.

The following points in regard to germination are brought out by these curves:

(1) Greatest germination was attained with a ¼-inch depth of cover, which was the shallowest; and the second greatest was with ⅜-inch depth. The ½-inch and ⅝-inch covers showed about the same amount, due to the fact that on the ⅝-inch broadcast plot the depth of cover was reduced by washing, with a consequent marked increase in germination for that plot. The deeper sowings showed still less, the ¾-inch plot taking fifth place, and the 1-inch plot sixth place.

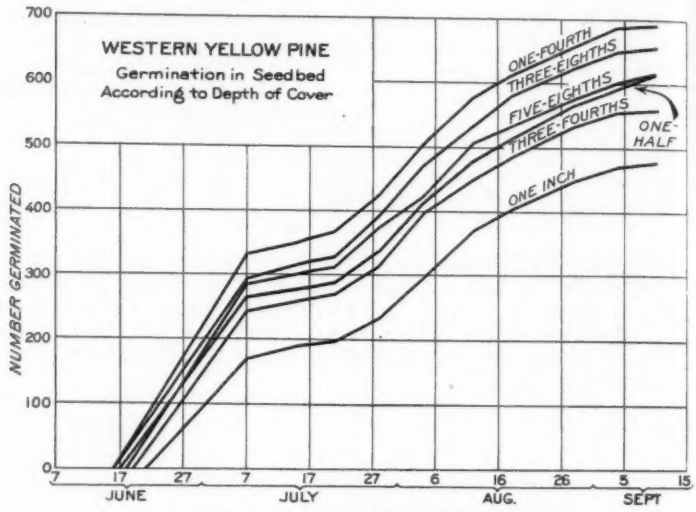

FIG. 1.—Weekly march of germination, 1913: Depth of cover

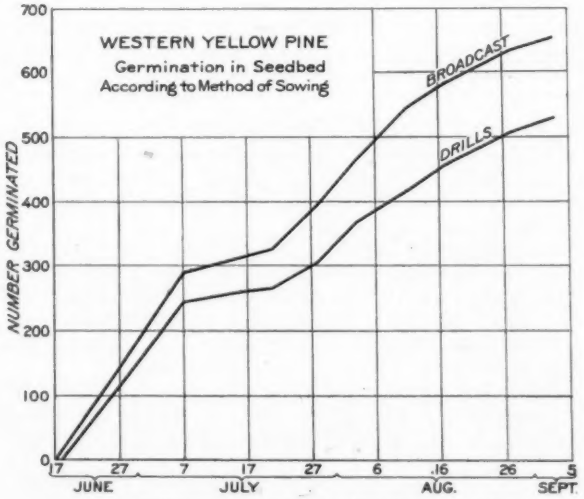

FIG. 2.—Weekly march of germination, 1913: Method of sowing

(2) Germination started five days earlier under the shallowest cover than under the deepest.

(3) The shallowest sowings, ¼ inch and ⅜ inch, showed the most rapid rate of germination.

(4) The period of most active germination occurred in the last half of June and the first half of July, from three to four weeks after sowing.

The survival and development of the stock in the seed bed at the end of the season, and the results in the transplant bed, are shown in Table III.

TABLE III.—*Survival and development of western yellow pine in seed bed and transplant bed, under different depths of cover and methods of sowing, 1913*

Depth of cover	Method of sowing	Seed beds						Transplant beds			
				Average measurements					Fall, 1915		
		Total germination	Survival	Length of root	Length of stem	Weight of root	Weight of stem	Spring, 1915, survival	Survival	Diameter of stem	Height of stem
		Number	*Per cent*	*Inches*	*Inches*	*Grams*	*Grams*	*Per cent*	*Per cent*	*Mm.*	*Mm.*
¼ inch	Drills	714	76.5	9.30	2.20	3.40	5.80	79.0	76.2	4.90	6.00
	Broadcast	702	79.8	9.20	1.80	2.40	3.85	83.0	81.0	4.50	4.90
	Average	708	78.1	9.25	2.00	2.90	4.82	81.5	79.1	4.70	5.45
⅜ inch	Drills	577	79.0	9.30	2.40	3.00	5.43	83.2	82.5	4.90	5.60
	Broadcast	776	83.1	9.50	1.80	2.35	3.60	86.0	83.0	4.90	6.00
	Average	676	81.4	9.40	2.10	2.68	4.52	84.5	83.8	4.90	5.80
½ inch	Drills	656	77.3	9.70	2.40	3.08	5.65	80.0	77.7	4.80	5.90
	Broadcast	565	85.3	10.60	2.10	3.13	4.45	86.5	82.2	4.70	5.70
	Average	610	81.0	10.15	2.25	3.10	5.05	83.9	80.6	4.75	5.80
⅝ inch	Drills	505	59.8	10.10	1.90	3.15	4.20	87.0	84.0	4.90	5.90
	Broadcast	[a] 733	68.2	11.50	2.10	3.25	4.65	89.9	87.3	4.50	5.40
	Average	[a] 619	64.8	10.80	2.00	3.20	4.42	88.9	85.7	4.70	5.65
¾ inch	Drills	449	65.2	9.50	2.00	2.70	4.60	92.7	84.3	4.50	5.80
	Broadcast	694	63.1	11.10	2.00	3.05	4.15	56.5	55.5	4.30	5.00
	Average	572	64.0	10.30	2.00	2.88	4.38	64.5	61.9	4.40	5.40
1 inch	Drills	366	64.8	9.10	1.90	2.55	4.70	83.3	83.3	4.20	4.90
	Broadcast	621	72.3	9.70	2.00	2.50	3.90	85.6	84.6	4.90	5.10
	Average	494	69.4	9.40	1.95	2.52	4.30	85.1	84.5	4.55	5.00
Summary											
Total or average for ¼, ⅜, and ½ inch:											
Drills		1,947	77.5	9.43	2.33	3.16	5.63	80.8	78.9	4.83	5.83
Broadcast		2,043	82.6	9.77	1.90	2.63	3.97	84.9	82.1	4.70	5.53
Total or average for all depths:											
Drills		3,267	71.7	9.50	2.13	2.98	5.06	83.1	80.4	4.70	5.68
Broadcast		4,091	75.1	10.27	1.97	2.78	4.10	80.9	78.3	4.63	5.35

[a] Depth of cover decreased by washing, causing increase in germination.

The averages for the broadcast and drilled plots shown in Table III bring out the following points:

(1) The survival in the seed bed is highest for the ⅜-inch covered plots, followed closely by the plots with ½-inch and ¼-inch cover.

(2) The seedlings from the plots covered ⅝ inch have the longest roots, those from ¾ inch and ½ inch covers coming next.

(3) The seedlings from the plots covered ½ inch show the largest stems and the heaviest tops.

(4) The heaviest roots were produced on the seedlings from the plots covered ⅝ inch. The comparison between length and weight

of roots is not exact, however, since roots were simply dug in the ordinary way with a spade and it was impossible to obtain the entire root.

(5) The figures for survival in the transplant bed, both after the first year and at the end of the second year, are too irregular to indicate a clearly defined influence of the depth of cover on the survival of transplants.

(6) The transplants from the plots with shallow covers show a slightly better development than those from the more deeply covered plots. This is probably due to the earlier and more vigorous germination in the shallow plots.

The notes taken on the condition of the seedlings when removed from the seed bed are as follows:

Western yellow pine at ¼ inch: Seedlings dark green and thrifty, but apparently many seeds failed to germinate because either entirely or partly on the surface. Radicals of some appear to rise into the air leaving crown in the soil. Practically every germination for several weeks after July 10 was lost through damping-off and drought.

At ⅜ inch: Fine, healthy appearance.

At ½ inch: Good, thrifty appearance.

At ⅝ inch: Fairly healthy appearance. Damping-off very active.

At ¾ inch: Seedlings pale green and inclined to be poor form. Damping-off bad.

At 1 inch: Seedlings rather deformed, pale and unthrifty, tending to damp-off.

Since practically all loss was due to damping-off, the lower survival rate in the deeper covers seems to indicate greater susceptibility to the attacks of damping-off fungi. The root systems of the stock from the lesser depths were more bushy, although perhaps not so long, as those from the ⅝-inch and ¾-inch plots.

Germination and survival figures for the experiment conducted at Trapper Creek nursery in 1914 are shown in Table IV.

TABLE IV.—*Depth of cover germination and survival percentages, Trapper Creek, 1914*

Depth of cover	Germination at successive observation dates, in percentages of total germination					Total germination of seed sown		Survival of seedlings germinated	
	June 15	July 1	July 15	July 22	Oct. 1				
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*
¼ inch	12.3	70.5	15.3	0.0	1.9	163	27.2	158	96.9
⅜ inch	2.2	72.5	24.8	0.0	0.5	177	29.5	154	87.0
½ inch	3.0	86.2	7.2	1.8	1.8	166	27.7	157	94.6
⅝ inch	0.0	81.7	15.6	0.7	2.0	148	24.7	135	91.2

The following points are brought out by Table IV:

(1) Although the earliest germination occurred on the plots with shallower cover, the plots with deeper cover showed equal or greater total germination by July 1.

(2) Greatest total germination was under the ⅜-inch cover, with the ½-inch and the ¼-inch next in order, and the ⅝-inch, the deepest, in the last place.

(3) The least depth, ¼ inch, showed the highest percentage of plants surviving at the end of the season, with ½ and ⅝ inch next in order, and ⅜ inch last. In percentage of seed sown, however, survival at ⅜ inch is very much better than at ⅝ inch.

METHODS OF SOWING SEED

SUMMARY

Sowing in long open drills permits pruning of roots in place and facilitates cultivation. Because of the economy of space and time, broadcast sowing has been generally adopted at the Savenac and Boulder nurseries.

The experiments at Priest River in 1913–14 show, from the standpoint of economy of seed, that the evidence is consistently in favor of broadcast sowing. This method produced highest germination, highest survival, and best development of the plants.

Because of the lack of facilities for large-scale production, it was impossible to investigate accurately the difference in economy of time and space between broadcast and drill sowing. These questions have, however, already been worked out at the Savenac nursery, with results in favor of broadcasting for northern Rocky Mountain conditions. It may, therefore, be definitely concluded that for conditions in this region where watering is not possible, and where it is not necessary to cultivate between the rows to conserve moisture, yellow pine seed should be sown broadcast.

PROCEDURE

The principal experiment in this series was identical with that carried on at the Priest River station in 1913 in the depth-of-cover study in the Meadow nursery. It is therefore unnecessary to repeat the description of operation already given.

In order to obtain data on the effect of fall sowing upon methods, two more beds were sown in the Meadow nursery in the fall of 1913. No. 1 was sown broadcast and No. 2 in drills, using the same seed used in the spring-sowing experiment, covered with clean sand to a depth of ⅜-inch after careful spading and preparation of the beds. Protection and watering were as for spring sowing. Six representative areas, 1 foot square in the broadcast bed and one drill in the drilled bed, were selected for intensive counts which were made weekly during 1914.

DATA

The results of the 1913 spring-sown study at Priest River have already been assembled in Figures 1 and 2 and Table III. The summary of Table III has been prepared to show contrasts due to differences in method of sowing rather than depth of cover. Reference is made to these data, in regard to the essential points brought out, as follows:

(1) Germination in the broadcast plots was consistently greater than in the drilled plots, or 25 per cent more for all depths. For the three shallower depths, however, the average of the broadcast plots was only 5 per cent greater, so that for the depths which will be used in practice the advantage over the drills is very slight. The greater difference in the deeper sowings was due perhaps to the fact that the cover on the three broadcast plots was decreased somewhat by watering, thus probably increasing the germination.

(2) During the first month germination in the drilled plots was more rapid. By the middle of July the broadcast plots were in the lead in point of numbers. It evidently takes the seedlings in the

broadcast plots a little longer to break through the ground, possibly because in the drills the combined lifting force of many seedlings is concentrated along a narrow line. Figure 2 shows graphically the rate and amount of germination.

(3) Survival in the seed bed, in percentage of the number that germinated, was higher for the broadcast plots, both for the average of the three lesser depths (5.1 per cent) and also for the average of all depths (3.4 per cent). The comparatively higher survival in the broadcast plots is due to greater susceptibility of the seedlings along the drills to attack from damping-off.

(4) In general, the stock from the broadcast plots showed a longer root and a shorter top than that from the drills, and the tops and roots were, on the whole, lighter in weight. The broadcast method produced the largest seedlings, except for the ⅜-inch and ¼-inch depths, and the drill method produced the heaviest plants, except for the ⅝-inch depth.

(5) The stock raised by the broadcast method showed a higher survival in all cases, except for the lot raised with ¾-inch cover. The latter made such a radically different showing from any of the rest that it can safely be assumed to have been injured either during transplanting or later.

(6) Measurements of both seedlings and transplants show that the stock raised in the drills had longer roots and tops. This is due to greater competition for light and root room in the case of seedlings crowded together in drills. It really means that the drills produced an inferior grade of stock compared to the broadcast plots and is an argument in favor of broadcast sowing.

A comparison of the amount of germination in the fall-sown beds is of no value, for the reason that mice got in during the winter, in spite of protective screens, and did more or less damage. Therefore the germination figures have not been tabulated. The total amount of germination during the season was 25 per cent greater in the drills than in the broadcast beds, but this may only indicate that more of the broadcasted seed was eaten than of that in the drills.

Loss in the drilled bed was almost 50 per cent greater than in the broadcast bed, showing a marked advantage in favor of broadcasting.

Plants from the drills had longer, more spindling tops than those from the broadcast bed, an additional argument in favor of the latter method.

DEGREE OF SHADE

SUMMARY

As earlier nursery experience in other regions had shown that the tender first-year seedlings of many conifers were benefited by being partially shaded from the direct rays of the sun, it was the practice to use shade on western yellow pine beds in the earlier nursery work in this region. By 1913, however, when this study was started, shading had been discontinued for yellow pine at Savenac and Trapper Creek nurseries, for general observations indicated that it was unnecessary. The experiments at Priest River were undertaken to obtain definite information on this point.

The basis for drawing conclusions was the effect of the different degrees of shade upon germination, survival, growth, and development of seedlings, and survival and growth of transplants.

Germination is affected by the influence of shade upon temperature and moisture content of the soil. Shade influences survival by reducing excessive water loss of the young plants in transpiration, by decreasing the surface temperature and evaporation from the soil, and by making conditions more favorable for the growth and spread of damping-off fungi. Shade affects the survival and growth of transplants indirectly through its effect upon the rate of germination, since the seed which germinates earliest produces the largest and most vigorous seedlings for transplanting.

Practically all the evidence from these experiments strongly supports the conclusion that western yellow pine spring-sown seed beds should not be shaded where artificial watering is possible, under the conditions in northern Idaho and western Montana. Duplicate experiments in two successive seasons, one of which was moist and favorable and the other was unusually hot and dry, uniformly show that the largest and most rapid germination, greatest survival, and best growth in the seed bed is obtained without shade, and that the unshaded seedlings make, on the whole, the best record in the transplant beds. There does not even seem to be any advantage in the temporary use of light shade during the hottest and driest part of the season, if water is frequently applied.

The optimum condition for the seedlings of this species appears to be full light and direct exposure to the sun at all times.

PROCEDURE

Two sets of experiments were included in this study, one in 1913 and one in 1914. The 1914 series was intended to check the results obtained in 1913 under different seasonal conditions, and to compare early spring sowing with the late spring sowing. The two seasons represented a wide contrast, 1913 being cool and moist, and 1914 unusually hot and dry. All plots were located in the Meadow nursery in connection with similar shading experiments with Douglas fir and western larch.

The original plan for the 1913 experiments included only two degrees of shade—one-quarter shade and no shade—since previous nursery experience had indicated that one-half shade was probably too heavy for an intolerant species like yellow pine. The no-shade and one-quarter shade plots were sown June 6, the late sowing being due to the unusually late season that year and unavoidable delays in getting the new nursery ready for sowing. At the end of the season, however, it was thought worth while to make a comparison between these two plots and another plot sown June 6 in a near-by bed which had been given one-half shade. This plot differed essentially from the other plots only in area, position in the bed, and degree of shade. Source of seed, date and method of sowing, depth of cover, character of soil, and other details of treatment were the same for all three plots.

One-half shade was included as a regular feature of the 1914 series, and three plots, one for each degree of shade, were sown May 6 in adjacent beds. Except for the degree of shade, all essential features of treatment were similar for the three plots.

Seed collected and extracted at the experiment station in the fall of 1912 was used for both the 1913 and 1914 experiments. All seed was sown broadcast and covered with clean sifted sand to a depth of

½ inch in 1913 and ⅜ inch in 1914. Sand was spread by one-hand leveling boards and the depth was gauged by numerous toothpicks inserted to project ⅜ inch above the sowing surface.

The one-quarter shade and no-shade plots in 1913 were 4 feet square and occupied one-third of the beds. They were sown with about 375 seed per square foot by distributing as evenly as possible an equal amount of seed over each plot, the seed being weighed out to centigrams. The one-half shade plot was 2 feet square in the ½-inch cover, broadcast plot, and was also sown at the rate of 375 seeds per square foot by weight.

In the 1914 tests all plots were 3⅓ feet by 4 feet, the short dimension being caused by a vacant space left at the ends of each bed so that conditions surrounding the end plots might be similar to those surrounding the plots in the middle of the bed. Three equal quantities of seed, weighed out to centigrams so as to provide about 350 seeds per square foot, were evenly distributed over the plots.

To prevent damping-off, the 1914 plots were sprinkled with dilute sulphuric acid applied two-thirds before sowing and one-third after covering, at the rate of $\frac{3}{16}$ fluid ounce of acid to 1½ pints of water per square foot. The 1913 plots were not sterilized.

Germination and survival counts were restricted to certain parts of each plot because of the limited time available for such work, except for the small one-half shade plot of 1913, which was counted completely. In the other 1913 plots a counting area 2 feet square was marked off in the center by pressing lath into the soil edgewise. In the 1914 plots two areas 1 foot square were used. These were centrally located about 1 foot from either side of the bed and marked by bent telephone wire laid on the surface and fastened by pegs.

Standard shade screens, made by nailing common lath to an outside frame of 2-inch strips at a distance of one lath width apart, were used to furnish one-half shade. One-quarter shade was provided by the use of lath sawed in half lengthwise, and spaced 1½ full lath widths apart. Such a frame distributed the light and shade more uniformly than if full-width laths spaced 3 widths apart had been used. The no-shade plots received full light, except for a little shade along the edges of the south side and ends of each bed caused by the 2-inch bars of the protective frame and the ½-inch mesh wire of the screens.

Beds were laid out in an east-and-west direction so that the lath shadows would move from west to east. During both years shade frames were left on continuously from the time of sowing until the end of September.

Watering was carefully regulated in each season so as to give uniform treatment to all plots. With the nozzle set at a certain point, all beds were sprayed for the same number of minutes at each watering.

The stock raised in 1913 was transplanted May 1 and 2, 1914, and was divided into separate lots according to the degree of shade it had received. Part of the 1914 stock was transplanted in November, 1914, and was kept separate according to degree of shading and months of germination. The rest of this stock, separated only according to degree of shading, was transplanted April 26, 1915. All transplanting was done with a standard Yale board in trenches dug with a spade, and the work was uniform for all lots.

Counts of germination and survival were made about once a week after germination started during both seasons. At the end of the season a count of all living seedlings in the counting areas was made as a check on the total brought forward weekly. Also a final count of the total number of surviving plants outside the counting area was made to determine how closely the counted areas represented the rest of the plot. Survival counts of the transplants were made in the early summer and fall of 1915.

When seedlings were taken up for transplanting in the fall, a sufficient number from each plot in each bed to give a good average were selected arbitrarily, and measurements of length of main tap root and length of stem to tip of bud were taken. The plants were carefully dug to a depth of about 18 inches, and the soil was loosened from the roots with the fingers so as to bring out practically all of the main root system with the plant. In addition, the 1913 samples were washed and surface-dried and divided at the ground line, the two lots of roots and tops being weighed to centigrams. The 1914 samples were not weighed, but were measured to obtain the average length of leaf in the main top and the diameter of the stem at the ground line. In the fall of 1914 measurements were taken separately according to month of germination. Measurement of the length of root was omitted for the stock taken from the 1914 beds in the spring of 1915.

In the fall of 1915 each tenth transplant from each lot in the transplant bed was measured to determine the average height of stem and diameter at ground line.

At the time seedling stock was measured about five plants typical of those with average measurements were selected from each lot and pressed. Photographs were made of typical seedlings from each of the three degrees of shading and also of seedlings from the unshaded bed, to show the relation between month of germination and size of the plants.

DATA

The evidence brought out by the experiments is, briefly, as follows:

The unshaded bed in 1913 produced much the largest total germination for the season, one-quarter shade being 20 per cent less, and one-half shade 50 per cent less. The same marked relation is shown by the 1914 beds, although the decrease in germination in the shaded beds is proportionally not so great.

The rate of germination was most rapid in the unshaded beds in both years. In 1913 the ratio was 45 for no shade, 35 for one-quarter shade, and 20 for one-half shade. The relation in 1914 is shown graphically by the curves in Figure 3. The general form of the curves is the same, but the curve for the unshaded bed rises more rapidly than those for the shaded beds.

Percentage of germinated seedlings surviving at the end of the season is greatest in the unshaded beds in both years, both for the individual months of germination and for the plots as a whole. Expressed in percentage of plants germinated, the proportion in the 1913 beds was 94.6 per cent for no shade, 78.4 per cent for one-quarter shade, and 85.9 per cent for one-half shade. In the 1914

beds the percentage of germinated seedlings surviving was practically the same for no shade and one-quarter shade (85.3 and 85.7), but was distinctly less for one-half shade (78.5).

The total number of surviving plants at the end of the season, in the entire beds in 1913, including those in the germination-count plots, when expressed in terms of the percentage of seed sown, made a distinct showing in favor of no shade. The percentage for

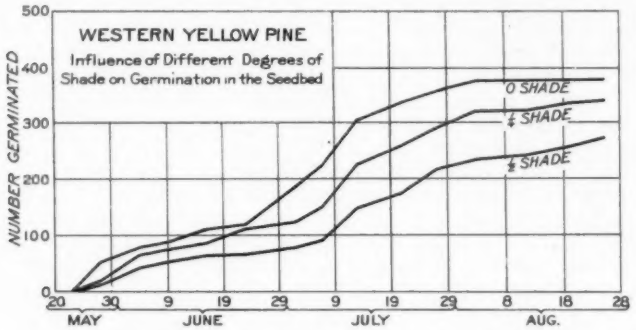

FIG. 3.—Weekly march of germination, 1914: Degree of shade

no shade was 64, for one-quarter shade next at 51 per cent, and one-half shade least with 48 per cent. Losses in the 1914 beds are shown in detail in Table V.

TABLE V.—*Losses by months under different degrees of shade, 1914 beds*

Month	Loss, no shade			Loss, ¼ shade			Loss, ½ shade		
	Dead seedlings	Percentage of germination to date	Percentage of season loss	Dead seedlings	Percentage of germination to date	Percentage of season loss	Dead seedlings	Percentage of germination to date	Percentage of season loss
June	23	12.2	58.9	18	6.1	46.1	12	15.4	20.0
July	14	3.7	35.9	17	3.4	43.6	22	9.3	36.7
August	1	0.3	2.6	1	0.2	2.6	9	3.2	15.0
September–October	1	0.3	2.6	3	0.6	7.7	17	5.9	28.3
Season loss	39	10.1	100.0	39	7.5	100.0	60	20.8	100.0

The largest and best developed plants were obtained from the unshaded bed, the second best from the one-half shaded bed, and the smallest from the one-quarter shaded bed.

The fact that there is a marked difference in size of seedlings according to month of germination, as shown in Figure 4, is an additional argument in favor of no shade. As the earliest germination occurs without shade it should naturally follow that a greater proportion of large, well-developed plants will be produced without shade than when either one-quarter or one-half shade is used.

For the 1913 beds, stock given one-half shade shows the greatest percentage of transplants alive both in the spring count (after one season) and the fall count (after two seasons), with one-quarter shade second and no shade last. The percentages were 95, 92, and 83, respectively. The better survival for the one-half shade stock possibly may be accounted for because of the lesser density of plants in the one-half shade plot, or because of some unknown variable in the transplant bed.

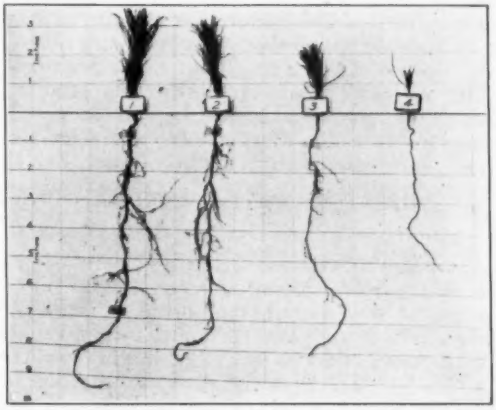

FIG. 4.—Effect of early germination on size of seedlings (*Pinus ponderosa*). Comparison, at end of season, of seedlings germinating in May (1), in June (2), in July (3), and in August (4)

Survival of transplants from the 1914 beds given in Table VI corresponds in the spring count of 1915 with the development of the seedlings and shows 63 per cent for no shade, 61 for one-quarter shade, and 59 for one-half shade. Survival in the fall, in percentage of the number transplanted, was greatest for the one-quarter shade stock (56), with no shade next (52) and one-half shade lowest (47).

TABLE VI.—*Seedling measurements and transplant data by month of germination, fall transplanting, series of 1914*

Degree of shade	Month of germination	Seedling measurements				Transplant data			
		Length root	Length stem	Length leaf	Diameter stem	Survival		Height stem	Diam stem
						First spring	First fall		
		Inches	*Inches*	*Inches*	*Mm.*	*Per cent*	*Per cent*	*Inches*	*Mm.*
No shade	May	11.6	2.7	1.19	1.9	94.9	93.1	4.3	3.4
	June	10.2	2.4	1.07	1.8	75.8	62.8	3.6	3.0
	July	9.2	1.7	0.82	1.3	53.5	44.5	3.4	2.8
	August	5.4	1.1	0.48	1.2	10.0	0.0		
	Mixed					70.2	57.9	3.5	3.0
Weighted average		9.1	1.7	0.89	1.5	63.1	51.7	3.7	3.0
One-quarter shade	May	9.5	2.1	0.90	1.5	92.8	91.0	3.2	2.8
	June	8.7	1.8	0.87	1.3	85.0	70.0	3.1	2.6
	July	8.1	1.6	0.78	1.2	63.7	54.8	2.8	2.0
	August	5.6	1.2	0.48	1.2	40.0	35.0	1.8	1.9
	Mixed					74.0	57.0	2.8	2.5
Weighted average		7.9	1.6	0.75	1.3	60.8	56.5	2.7	2.4
One-half shade	May	10.5	1.9	0.99	1.4	97.8	97.0	3.4	2.6
	June	10.5	1.5	0.86	1.3	70.4	58.2	2.6	2.3
	July	8.7	1.4	0.71	1.2	70.4	45.4	2.8	2.2
	August	6.5	1.0	0.50	1.2	4.3	3.3	1.7	1.7
	Mixed					62.8	56.5	3.1	2.8
Weighted average		9.0	1.4	0.86	1.2	58.9	47.3	2.7	2.3

The survival figures for the transplants are rather contradictory and seem to show that the influence of shading in the seed bed has at least partly disappeared and given place to other and more direct influences in the transplant bed itself. The fact that the shaded stock made a slightly better showing may indicate that shade helps to fit the plants to withstand the shock of transplanting. This does not seem reasonable, however, as the more probable effect of shade would be to make them less resistant to severe conditions.

The size of the transplants in the first test did not vary in accordance with the shade received, those receiving one-half shade being much the largest, and the others about equal. The unshaded transplants obtained next year were distinctly the largest, however, with one-quarter shade stock slightly larger than that from one-half shade.

AMOUNT OF WATER WITH OR WITHOUT CULTIVATION

SUMMARY

It was to obtain some definite information as a basis for the standardization of watering western yellow pine that the following experiment was undertaken, bringing out the effect of the different kinds of watering and cultivation upon the growth and development of the stock, first as seedlings and later as transplants.

It is evident that the cheapest method of watering is to water heavily at rather infrequent periods. If water is more difficult to obtain in large quantities, lighter and more frequent watering, with cultivation to conserve the moisture, might be most profitable. Or, if the watering became very expensive, it might pay better to cultivate frequently enough to maintain a good dust mulch and retain in the soil as much as possible of the natural rainfall.

While the combination of moderate watering with cultivation produced the best results in this experiment, the difference in favor of this treatment was comparatively small. In order to cultivate it was necessary to sow in drills. In the second section of this report it was demonstrated that there was a material saving of seed, labor, and space when seed was sown broadcast. The slightly increased growth of the plants due to cultivation would hardly justify the lack of economy due to drill sowing where plenty of water was available. The cost of cultivating between drills, which has to be done with great care in order to avoid injury to the plants, would be an additional argument against cultivation. Broadcast sowing, with rather heavy watering at frequent intervals sufficient to maintain an average water content of more than 50 per cent of dry weight, is therefore unquestionably the best method for use at large nurseries where an abundance of water under pressure is to be had.

In small ranger nurseries where water is scarce or it is inconvenient or expensive to apply it, very good results may be obtained in the western part of the northern Rocky Mountain region on moderately heavy moisture-retentive soil, by raising the stock in drills and cultivating the surface either without artificial watering or with a moderate amount of water applied at times of special need.

PROCEDURE

Beds in the Meadow nursery were carefully prepared for sowing by spading the surface and mixing in sharp sand to loosen the top soil. Seed was sown in drills June 6, 1913, the late sowing being due

to the unusually late season and unavoidable delay in getting the beds ready. About 375 seeds (as determined by weight) were used per drill, that number being sufficient to produce an estimated stand of 200 plants per drill four feet long. Drills were 3 inches apart. One-half inch of clean sand was used for covering seed.

The beds were given one-half shade from time of sowing to the end of the season, except when frames were removed for short periods to check damping-off. Protection from birds and rodents was provided by a Pettis seed-bed frame.

Counts of germination and loss were made about once a week from the time of first germination until September, with a final count in mid-October. Plants were left in the beds for two seasons and were counted again at the end of the second season.

All beds were watered equally during the period of heaviest germination up to August, in order to establish a fairly complete stand before differentiation in treatment began, since it was not desired to include in this study the effect of watering upon germination.

After the first week in August the different beds were given the following kinds of watering treatment:

(1) No artificial watering was done, and the surface was cultivated every fourth day and as soon after every rain as the ground could be worked. A uniform dust mulch was maintained in this way.

(2) Two quarts of water were applied per square foot every fourth day. Surface was cultivated after every rain and as soon after watering as the ground could be worked.

(3) One quart of water was applied per square foot every other day. No cultivation was given.

The differentiation in treatment was delayed because of the slow germination due to the late sowing. Although the treatment was kept up during the last three weeks in August and throughout September, the period was not long enough to affect the plants materially. It was therefore decided to continue the experiment through a second season and to make the contrast between treatments great enough to cause differences in growth in spite of the tendency of the plants to adjust themselves to changed conditions.

The following different treatments were given the second season:

(1) No artificial watering was done. Surface was cultivated as soon after every rain as the ground could be worked. It was also cultivated often enough between rains to maintain a dust mulch.

(2) A moderate amount of water was given at the end of each week, the amount being regulated so that the sum of the rainfall and artificial water made a total of 0.75 inch per week. The water applied artificially was reduced to inches by timing the flow with the nozzle set at a certain point and measuring the cubic inches of water discharged per minute. The surface was cultivated after each watering and each rain.

(3) The bed was heavily watered, enough water being applied to make a total, when combined with rainfall, of 0.75 inch for each one-half week. Watering was done on alternate Tuesdays and Wednesdays, as representing the middle of the week and again on Saturdays, thus given an interval of approximately one-half week between applications, not counting rains.

When the precipitation during the week amounted to more than 0.75 inch in the case of bed 2, or to more than 0.75 inch for the semi-weekly period in the case of bed 3, the total amount of precipitation was noted, but the surplus was not carried forward into the next period, as the amount of the surplus was the same for all beds.

During the growing season soil samples were taken regularly each week from each of the three beds, as follows: Surface inch, 2 to 6 inch core, 7 to 12 inch core, and 13 to 18 inch core. The moisture content of each core was determined.

About one-half of the stock was transplanted in November and one-half in April. In the fall, at the time of transplanting, measurements were taken of 100 plants to show length of root in inches, length of stem in inches, diameter of stem at ground line in millimeters, and length of leaf in inches.

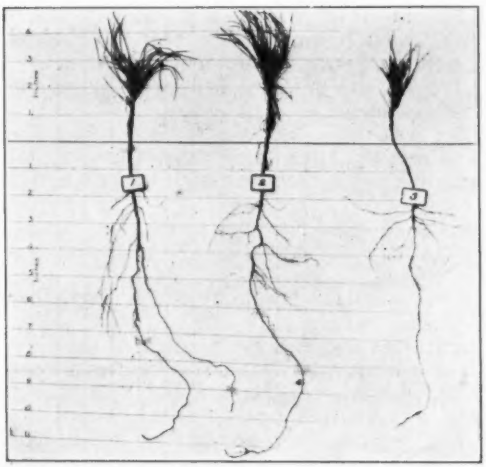

FIG. 5.—Watering versus cultivation. Average seedlings from three beds which received heavy watering only (1), watering and cultivation (2), and cultivation only (3)

A survival count was made in the early summer and in the fall of 1915, at which later time measurements of height and diameter of stem were made.

When the stock was transplanted, five seedlings, typical of average measurements, were selected from each bed and pressed. One of each of these lots of samples, photographed in order to illustrate the difference in development due to watering treatment, is shown in Figure 5.

DATA

Seed-bed germination and survival have little bearing on the study, because most of the germination was purposely allowed to take place before differentiation in watering treatment began. The relative merits of the three methods of treatment must, therefore, be judged by their effects upon the development of the seedlings and the growth and survival of the stock in the transplant beds. The essential records are included in Tables VII, VIII, and IX.

TABLE VII.—*Water content of seed-bed soil under different methods of watering, second season, 1914*

Method of treatment	Percentage of average moisture content				Maximum at 1 to 6 inches	Minimum at 1 to 6 inches
	Surface inch	1 to 6 inch core	7 to 12 inch core	13 to 18 inch core		
					Per cent	*Per cent*
Cultivation only	23.5	39.0	42.1	43.5	54.3	14.5
Cultivation and watering	33.4	54.1	57.8	54.7	69.0	40.4
Watering only	42.0	56.1	57.5	60.3	67.8	46.2

TABLE VIII.—*Survival, and growth of seedlings under different methods of watering, 1913–14*

Condition of seed			Survival of seed germinating				Measurements, second fall			
Method of treatment	Germination		First fall		Second fall		Root length	Stem length	Leaf length	Stem diameter
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Inches*	*Inches*	*Inches*	*Mm.*
Cultivation only	759	63.2	509	67.1	331	43.6	11.7	2.3	1.9	1.8
Cultivation and watering	943	78.6	622	66.0	441	46.8	14.4	3.0	2.3	2.3
Watering only	753	63.2	484	64.3	298	39.6	13.6	2.8	2.1	2.1

TABLE IX.—*Survival and growth in the transplant bed under different methods of watering, 1915*

Season transplanted	Treatment	Survival of transplants		Measurements (fall)		
		Spring	Fall	Height	Diameter	Size factor *
		Per cent	*Per cent*	*Inches*	*Mm.*	
Fall	Cultivation only	95.4	82.0	3.5	3.2	5.60
	Cultivation and watering	91.8	82.5	3.7	3.2	5.92
	Watering only	90.2	78.6	3.4	3.1	5.27
Spring	Cultivation only	96.0	88.2	4.0	3.1	6.20
	Cultivation and watering	92.8	88.2	3.6	3.3	5.94
	Watering only	95.0	88.8	3.3	2.9	4.78

* One-half diameter multiplied by height.

The points brought out by the tables may be summarized as follows:

The largest plants were produced in the artificially watered beds. The beneficial effect of cultivation is clearly seen in the fact that the bed which was both watered and cultivated, even though it received only half as much water as the bed which was watered and not cultivated, produced noticeably larger plants than did the latter.

The soil moisture figures in Table VII show that the watered and cultivated bed had at all times practically as high a water content in the root zones as had the more heavily watered bed. The cultivating evidently helped to preserve moisture, but the greater growth in the cultivated bed must have been primarily due to the stirring of the soil rather than to the preservation of moisture. The exact effect of this stirring of the soil is not known, but it may have helped in aerating the soil and liberating plant food. One point indicated by the moisture-content data is that when the surface is cultivated, only half as much water is needed to maintain the soil moisture at a desirable point as when cultivation is not done.

The minimum moisture content figures show that soil moisture, even in the cultivated and unwatered bed, never approached a critical point. The hygroscopic moisture for similar soil in the vicinity is less than 4 per cent, and the lowest percentage reached was only 14.5.

Table VIII shows the measurements of the average 2-year-old seedlings from the three differently treated beds. The greater average size of the plants in the moderately watered and cultivated

bed could not have been due to more growing space, as there was a decidedly smaller number of plants in the other two beds throughout both years in the seed bed.

The stock from the moderately watered and cultivated bed maintained the lead attained in the seed bed and produced slightly larger and better developed transplants than that from the other beds. The most interesting point brought out by the transplants, however, as shown in Table IX, is the relative increase in size of the plants from the unwatered cultivated bed. In distinctly third place in the seed bed, as transplants they surpassed those from the heavily watered bed and almost attained first place, being practically as large as plants from the watered, cultivated bed. This seems to indicate that small size in the seed bed is not necessarily an undesirable feature for transplanting, if the plants are hardy.

The survival figures in the transplant bed show no clearly defined distinctions among the different treatments.

CONCLUSIONS

The following conclusions were reached from the results of the experiments:

(1) When clean, sharp sand is used and plenty of water is available, yellow pine seed in spring-sown beds should be covered to a depth of from ¼ to ⅜ inch.

(2) Where an abundance of water can be applied, highest germination and survival in the seed bed and best development of the plants can be obtained if seed is sown broadcast rather than in drills. Broadcast sowing is also more economical of labor and space.

(3) Shade is not only not necessary for western yellow pine seedlings in spring-sown beds in this region, but has a distinctly undesirable effect on the amount and rate of germination, the amount of survival, and the development of the plants. Shade should not be used at any time. The optimum condition for seedlings of this species seems to be direct exposure to the sun.

(4) In large nurseries where plenty of water can be applied, seed should be sown broadcast and the beds watered rather heavily at intervals frequent enough to maintain an average soil-water content of more than 50 per cent of dry weight.

(5) In small ranger nurseries where water is scarce or it is too inconvenient or too expensive to apply, very good results may be obtained in this region on moderately heavy moisture-retentive soil by sowing in drills and cultivating between the rows, either without artificial watering or with a moderate amount of water applied at times of special need.

YIELD CAPACITIES OF THE PURE YELLOW PINE TYPE ON THE EAST SLOPE OF THE SIERRA NEVADA MOUNTAINS IN CALIFORNIA[1]

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INTRODUCTION

East of the Sierra Nevada Mountains in California the predominating and most important forest type is western yellow pine (*Pinus ponderosa*). This type is represented by pure stands extending over large areas, in contrast with the characteristic mixed forest in which yellow pine is commonly found west of the Sierras and on the coast ranges. The lower precipitation on the east slope, the poorer soils, and shorter growing season, by creating conditions unsuitable for the more exacting sugar pine (*Pinus lambertiana*) and the firs, account for these pure stands and also for a generally lower rate of growth than is found elsewhere in the pine region. These conditions prevail over a considerable strip of country, and the east-slope pine in California is a part of merchantable stands of pure or nearly pure yellow pine ranging from western Washington and Oregon down to Arizona and New Mexico, all in many respects similar.[2]

Cutting in these western yellow pine forests is proceeding rapidly, both on national and private forest lands, and it is therefore important with regard to the possibility of obtaining new timber crops to study the productive capacity of the forest soils and to determine the amount of wood which can be produced with careful forest management. An immediate problem in practicing forestry on large areas of virgin forest is to develop a method for determining from the forest itself the productive capacity of a given area; for yellow pine stands vary tremendously in this region.

Yellow pine stands have been so little investigated that the technique of yield studies as applied to this species is itself a subject for investigation. The present study, which covered a large area in the eastern half of the Lassen National Forest, aimed not only to present preliminary information on yields of different qualities of forest land and on the probable rotations that will be used in growing the second crop of timber, but also to develop methods of procedure which might be applicable in similar investigations in other regions.[3]

FIELD METHODS

It soon became apparent that the traditional field methods for studying forest yields would have to be modified in order to meet the rather unusual conditions which were encountered in these stands.

[1] Received for publication May 26, 1925; issued December, 1925.

[2] The definition of a pure stand, which seems well established by usage, is one in which the dominant species forms 80 per cent or more of the total stand. This definition has been accepted and used in the present study.

[3] Assistance in field work was given by Duncan Dunning, E. N. Munns, and A. E. Wieslander; in office work by Miss D. H. Vinther and Vance S. Brown. The project here reported was carried out in 1919.

In the first place there was practically no true second growth in this locality. Almost the entire area was virgin forest in which no cutting at all had been done. Secondly, only one mill was cutting in the area, so that the opportunities for laying out plots and for obtaining taper measurements were exceedingly limited. Further, no volume tables were in existence which would be suitable for immature yellow pine and white fir (*Abies concolor*), that is, for trees up to about 150 years old; and therefore as an accompaniment to the main study it was clearly necessary to collect data for the construction of such tables.

The virtual absence of true second growth made it compulsory to select even-aged groups of the younger age classes growing within the virgin forest, such as commonly occur where fire or insects have created small openings within the main stand and where reproduction has come in and made a fully stocked stand. These groups by no means form an ideal substitute for true second growth, for it is quite certain that the mature trees surrounding them have influenced the growth of the younger classes, probably to a considerable extent. A further disadvantage is entailed by the fact that these even-aged groups within the virgin forest are commonly rather small and it is often almost impossible to lay out an isolation strip surrounding the plots. In the majority of cases, in order to obtain plots of a satisfactory size, it was necessary to include practically the entire group of young trees, every effort being made to keep the boundary lines sufficiently far out from the edge of the crowns so that too high an apparent yield would not be secured. With the great majority of the plots, also, the usual rectangular form could not be maintained, for the boundary lines had to conform to the shape of the plot on the ground.

The absence of cuttings and the undesirability of slashing down too many trees, together with the fact that cutting of trees on every plot would have slowed down the work very greatly, made it necessary to obtain age determinations by means of the increment borer. Cores were taken at breast height on several trees on each plot and the usual stump analysis measurements made on these cores. In selecting trees for boring, both large and small trees on each plot were taken, to be certain that the plot was even-aged and not of several ages.

In order to determine the number of years required by the trees to reach breast height, seedling analyses were made on or near practically every plot measured. The seedlings were selected, as far as possible, from those growing in small openings in the stand and apparently were dominant. Toward the end of the work, when an opportunity arose to lay out plots in the true second growth itself, similar seedling analyses were made in large openings created by clear cutting in the virgin stand. In this way a very good idea was obtained of the difference in rate of seedling growth in the virgin stand, where unquestionably the seedlings are badly oppressed, and in the open under conditions such as would follow cutting of the old timber.

In the determination of heights it was decided to measure only one or two trees in each of the four dominance classes (dominant, codominant, intermediate, and suppressed), rather than to attempt

a measurement of each individual tree on the plot. By this method a height-diameter curve for each plot or for each group of plots can be drawn, and in computing volumes the height indicated by the curve can be used with very little chance of serious error. Computations on several of the plots laid out by Gallaher [4] in west side pure yellow pine showed an error of from 1 to 2 per cent in using this method, the values where every tree was measured tending to run slightly higher than where the height-diameter curve was used. This short-cut method was felt to be fully justified, however, by the rate of speed which it made possible and because, so far as can be determined, any error introduced is likely to be on the side of conservatism.

Wherever possible, dominant and codominant trees on the plots were climbed and taper measurements taken, these trees later being used for the construction of a volume table. On part of the plots, also, sample trees were felled and complete stem analyses made. Occasionally wind-thrown trees were also measured.

Work was carried on from six camps well scattered over the area, a radius of several miles being covered from each. Thus it is believed that a sufficient portion of the entire area was studied to be representative of the entire range of conditions in yellow pine stands.

In all, 175 plots were measured: 132 pure yellow pine, 22 pure white fir, and 21 mixed stands. The site qualities as measured by mature heights ranged from about 170 feet to as low as 80 feet, thus practically embracing the entire range of site quality on the east side of the Sierras. The average plot was almost exactly one-fourth acre in area, individual plots varying from one-twentieth of an acre to nearly an acre in extent. For the construction of yellow pine volume tables approximately 150 trees were taken. About 25 white fir also were measured.

It can be seen from the preceding discussion that the field methods adopted differed in some respects from the traditional textbook methods for studying yield, a situation made necessary by limitations of the forest itself and of men and money to carry out the work.

OFFICE METHODS

The office methods used were in the main those established by custom for the construction of yield tables. As a preliminary step, of course, the tree-volume data had to be worked up and tables constructed. The first question encountered was the selection of a log rule on which to base the tables. The Scribner Decimal C rule, which is in current use in the Forest Service, is obviously unsuited for the study of future yields because of the large overrun of material sawed out as against the values from the rule. The information desired was the number of board feet of lumber per acre that could be obtained, not how many thousand feet the log scale would estimate. The Clark International rule was therefore selected because of its close approximation to mill scale. In determining on a standard of utilization on which the yield tables should be based, many individuals were consulted. The general consensus of opinion designated 8 inches in diameter at breast height as the smallest tree to be considered, and

[4] GALLAHER, W. H. SECOND GROWTH YELLOW PINE. Forestry Quart. 11:531–536, illus. 1913.

a 5-inch top as a cutting limit entirely within the bounds of possibility. Incidentally, these were the standards accepted by Gallaher for the west slope of the Sierras.

In the actual construction of the volume tables the data were worked up by three different methods, i. e., the conventional method, the frustum form factor, and the alignment method. The tables were then checked against the trees from which they were constructed and against each other, and it was found that the values derived by the different methods were generally exceedingly close, and that by each method the values from the tables checked well against the trees. In the same way cubic-foot tables were made and the board-foot tables checked against the cubic-foot tables, a conversion factor being used. Although it is recognized that the basis of data is rather small for construction of final volume tables for immature trees under east slope conditions, comparison of the values with those in the current tables indicates that the latter would be less suitable.

The values for a given total height and diameter class are higher on the east slope than on the west slope, using Gallaher's volume tables for the latter set of conditions. This is because the more rapid taper in the top of the east slope trees gives them a shorter top above the 5-inch merchantable limit than in the west slope trees. With trees of equal total height, those on the east slope thus have a greater merchantable length. If the tables were worked up on the basis of merchantable height instead of total height, the indications are that values would be higher for west slope than for east slope trees.

SITE CLASSIFICATION

A little consideration of the main problem, that is, the determination of the yield capacities of large areas of virgin forests, makes it clear that yield tables to be readily usable must be tied into some index which can be measured without difficulty. The principle that height of dominant trees at a given age or at maturity is a reasonably correct expression of differences in yield, or site quality, is so thoroughly established by both American and European experience that no objections could be seen to its adoption here, and consequently each plot was referred to the average height of dominant mature trees adjacent to the plot, usually four or five trees being measured to obtain a correct figure. One can readily see that this procedure makes possible at once an approximately correct site classification of the area where timber reconnaissance has been made. The original timber tally sheets show the occurrence of the mature timber by merchantable heights, and one readily picks out on the sheets the average maximum heights on a given forty. Then, after these heights have been entered on a base map, it is also easy to convert merchantable height to total height by adding the length of top above the merchantable limit used in the volume tables.

The concensus of opinion among foresters in this country seems to be that five site classes are sufficient, some writers, indeed, favoring three. After considerable discussion and study of the question it was decided to adopt the five-site quality classification and to use a difference of 20 feet in mature height as the interval between classes. This interval appears to be fairly well agreed upon and also has the great virtue of fitting the conditions in the forest. That is, in pure

yellow pine on the east slope the shortest timber is about 70 to 80 feet high, and the tallest about 170 feet, though very rarely stands nearly 200 feet high are encountered. On the particular area studied there are several fairly definite mature heights. Near the west side of Eagle Lake, for example, there is a large body of timber about 80 feet in height. On the easterly slopes in the same region, stands of 100 feet are found, and in the vicinity of Bogard Flat and on most of the buttes on the area, 120 feet is the common height of the virgin stand. The values finally selected therefore are: Site 1, over 150 feet; site 2, from 131 to 150 feet; site 3, from 111 to 130 feet; site 4, from 91 to 110 feet; site 5, from 71 to 90 feet. It is immaterial for this study whether this classification is the one finally determined upon for the region or whether it meets with the general approval of the profession; the data are such that any other better definition can be readily accepted, and the data tied in with it.

In accordance with this plan of site classification, the individual plots were sorted by age, 10-year age classes being used, and by site quality (Table I). The following data were computed for each individual plot and later plotted and curved on the basis of age classes: (1) Basal area per acre; (2) height of dominant trees; (3) diameter growth of dominant, intermediate, and suppressed trees; (4) trees per acre; (5) volume in board feet per acre; (6) volume in cubic feet per acre (Table II).

TABLE I.—*Distribution of plots in east slope yellow pine type by age and site* [a]

Age at breast height (years)	Distribution of plots						Age at breast height (years)	Distribution of plots					
	Total	Site 1	Site 2	Site 3	Site 4	Site 5		Total	Site 1	Site 2	Site 3	Site 4	Site 5
50	14	------	7	5	2	------	140	5	1	1	1	2	------
60	11	1	5	5	------	------	150	4	------	------	1	2	1
70	8	1	------	7	------	------	160	6	------	1	4	1	------
80	10	------	1	4	3	2	170	3	------	------	------	1	2
90	11	1	1	7	2	------	180	3	------	------	3	------	------
100	10	------	------	6	2	2	190	1	------	------	1	------	------
110	9	------	4	2	3	------	240	1	------	------	------	------	1
120	22	3	3	12	2	2							
130	14	1	4	8	1	------	Total	132	8	27	66	21	10

[a] Twenty-two plots of pure white fir and 21 plots of mixed pine and fir were also obtained.

TABLE II.—*Yield of pure yellow pine, Lassen National Forest, Calif.*

[Clark International rule, ⅛-inch kerf; values curved]

SITE 1 [a]

Total age [b] (years)	Number of trees per acre	Basal area per acre	Height of dominant	Average diameter at breast height	Volume per acre		Periodic annual growth	Mean annual growth	Board-feet per cubic foot
		Sq. ft.	*Feet*	*Inches*	*M. bd. ft.*	*Cu. ft.*	*M. bd. ft.*	*M. bd. ft.*	
60	356	168	53.0	9.3	3.5	2,320	0.35	0.06	1.51
70	251	197	64.0	12.0	13.5	4,300	1.00	.19	3.14
80	202	225	75.0	14.3	27.5	6,480	1.40	.34	4.24
90	174	252	86.0	16.3	43.5	8,500	1.60	.48	5.12
100	158	276	95.0	17.9	58.5	10,250	1.50	.58	5.71
110	146	297	103.0	19.3	67.5	11,680	.90	.61	5.78
120	138	314	109.0	20.4	74.0	12,800	.65	.62	5.78
130	134	328	113.5	21.2	79.0	13,650	.50	.61	5.79
140	133	342	117.0	21.7	83.0	14,350	.40	.59	5.78
150	132	353	120.5	22.1	86.8	14,950	.38	.58	5.81

[a] Mature heights, 151+ feet; yellow pine 80+ per cent; basis, 8 plots.
[b] Age at breast height is 20 years less than total age.

TABLE II.—*Yield of pure yellow pine, Lossen National Forest, Calif*—Continued

SITE 2[c]

Total age (years)	Number of trees per acre	Basal area per acre	Height of dominant	Average diameter at breast height	Volume per acre		Periodic annual growth	Mean annual growth	Board-feet per cubic foot [c]
		Sq. ft.	*Feet*	*Inches*	*M. bd.-ft.*	*Cu. ft.*	*M. bd.-ft.*	*M. bd.-ft.*	
60	417	142	41.0	8.0	1.0	1,060	0.10	0.02	0.94
70	280	165	51.0	10.4	8.0	2,660	.70	.11	3.01
80	222	189	61.0	12.5	17.0	4,260	.90	.21	3.99
90	196	215	71.0	14.2	27.0	6,030	1.00	.30	4.48
100	177	235	81.0	15.6	38.0	7,800	1.10	.38	4.87
110	164	255	91.0	16.9	48.0	9,110	1.00	.44	5.27
120	156	270	97.0	17.8	56.0	10,190	.80	.47	5.50
130	148	283	100.0	18.7	61.0	11,050	.50	.47	5.52
140	148	295	103.5	19.1	65.0	11,730	.40	.46	5.54
150	147	305	107.0	19.5	68.5	12,300	.35	.46	5.57
SITE 3[d]									
60	450	124	34.0	7.1					
70	331	143	42.0	8.9	3.0	1,180	0.3	0.04	2.54
80	273	164	52.0	10.5	9.0	2,600	.6	.11	3.46
90	229	183	62.0	12.1	17.3	3,900	.83	.19	4.44
100	209	202	71.0	13.3	25.7	5,400	.84	.26	4.76
110	191	219	81.0	14.5	34.0	7,000	.83	.31	4.86
120	178	230	85.0	15.4	40.7	7,970	.67	.34	5.11
130	167	237	88.0	16.1	45.0	8,600	.43	.35	5.23
140	162	243	91.0	16.6	47.7	9,100	.27	.34	5.24
150	158	249	93.0	17.0	50.5	9,570	.28	.34	5.28
SITE 4[e]									
60	526	100	28.0	5.9					
70	395	118	36.0	7.4	0.5	450		0.007	1.11
80	335	135	43.0	8.6	4.0	1,600	0.35	.05	2.50
90	296	152	52.0	9.7	8.4	2,650	.44	.09	3.17
100	270	169	60.0	10.7	13.7	3,750	.53	.14	3.65
110	247	182	68.0	11.6	20.2	4,800	.65	.18	4.21
120	221	191	73.0	12.6	26.0	5,570	.58	.22	4.67
130	205	200	76.5	13.4	30.0	6,070	.40	.23	4.94
140	189	205	79.0	14.1	33.0	6,500	.30	.24	5.08
150	177	209	81.0	14.7	35.8	6,830	.28	.24	5.24
SITE 5[f]									
60	727	81	21.0	4.5					
70	531	94	28.0	5.7					
80	429	108	35.0	6.8	1.0	850	0.1	0.012	1.18
90	375	121	42.5	7.7	3.5	1,700	.25	.04	2.06
100	337	133	50.0	8.5	6.5	2,400	.30	.06	2.71
110	296	143	56.5	9.4	10.2	3,050	.37	.09	3.34
120	273	152	61.0	10.1	14.5	3,550	.43	.12	4.08
130	252	160	63.0	10.8	18.3	3,920	.38	.14	4.67
140	238	166	64.5	11.3	21.5	4,280	.32	.15	5.02
150	229	171	66.0	11.7	24.2	4,600	.27	.16	5.26

[c] Mature heights, 131 to 150 feet; yellow pine 80+ per cent; basis, 27 plots.
[d] Mature heights, 111 to 130 feet; yellow pine 80+ per cent; basis, 66 plots.
[e] Mature heights, 91 to 110 feet; yellow pine 80+ per cent; basis, 21 plots.
[f] Mature heights, 71 to 90 feet; yellow pine 80+ per cent; basis, 10 plots.

The site 3 quality class was the one in which most of the work was done, 66 out of a total of 132 plots falling in that class. (See Table I.) Site qualities 2 and 4 also had a very fair representation of plots, but the values in basal area per acre and volume per acre for sites 1 and 5 were very poorly defined, and the curves are drawn in part by inference.

INDICATIONS OF THE DATA

It will be seen, considering first the chart for board-foot volume (fig. 1), that the curves flatten off very decidedly at about 90 to 100 years of age at breast height; in other words, that that age represents the culmination of current annual increment. A little study of the other charts will perhaps explain why volume growth falls off at 100 years. It is seen first (fig. 2) that basal area per acre also drops considerably at 100 years, and that height growth (figs. 3 and 4) culminates at that age, this curve especially showing a very sharp flattening. In diameter growth (fig. 5) and basal area growth of individual trees it is rather more difficult to say confidently that 100 years represents the culmination. Both of these curves show a very gradual flattening and a study of them alone would probably be of little assistance in determining rotation.

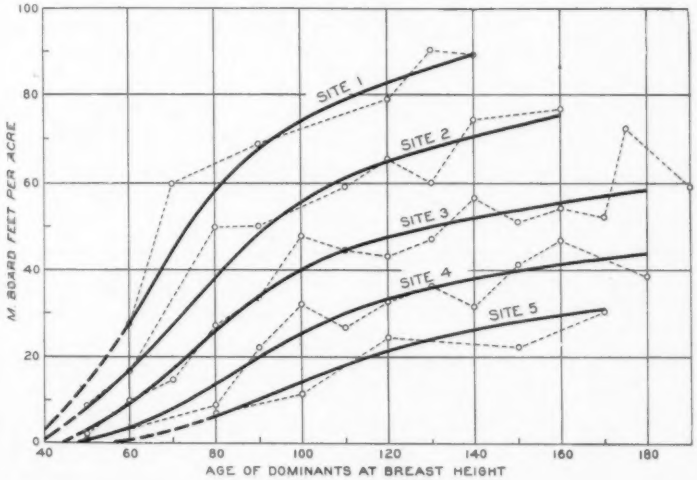

FIG. 1.—Yield per acre on age, board feet

The curves in Figure 6 showing trees per acre are unusually interesting. The upper curve gives total number of trees 4 inches in diameter up, while the lower curve shows trees per acre of merchantable size; that is, 8 inches and over. The latter curve indicates a rapid increase in the number of these trees per acre up to 80 years, and then a more gradual decrease in number up to the highest age reached by these studies. In other words, what evidently takes place in nature is that stands at 80 to 100 years reach a period of development when suppression, and perhaps other factors, begin to reduce the number of trees 8 inches and over more rapidly than smaller trees grow into that class. These curves thus show why and how volume growth begins to fall off after about 100 years age at breast height. Apparently height growth, total basal area growth, diameter growth, and number of trees per acre all tend to culminate at about

the same age, and obviously volume growth, which is a complex of these four factors plus form factor, must also culminate.

An examination of the volume curves (figs. 1 and 7) and of periodic annual increment (fig. 8) indicates that the better the site the earlier is the culmination of periodic annual increment. This seems to be in line with European and American observations.

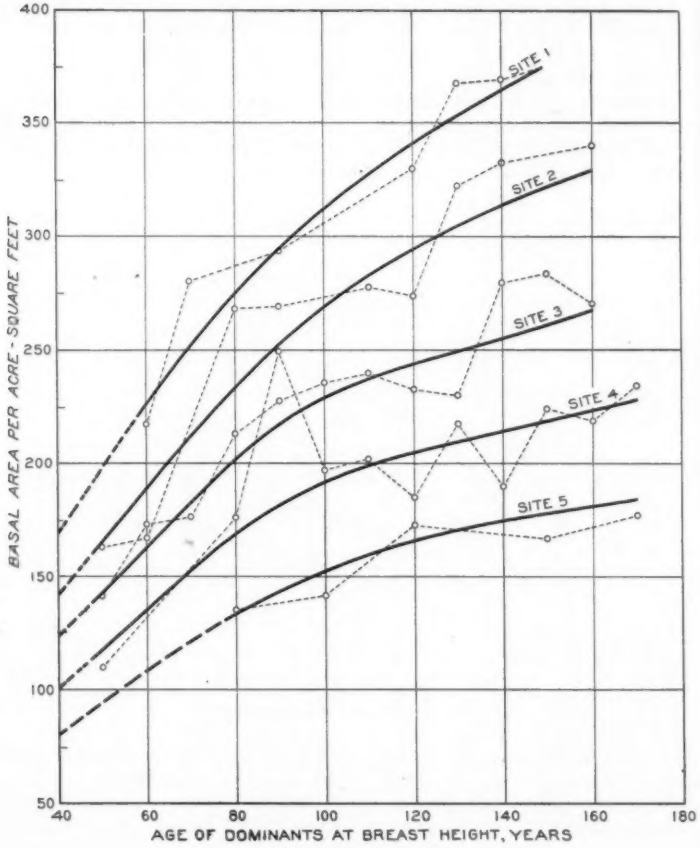

FIG. 2.—Basal area per acre on age

A study of the basal area curve (fig. 2) shows about equal intervals between sites, whereas in yield the interval between sites increases from poor to good sites. As far as a look into published data has shown, these tendencies seem to be in harmony with the results of more exhaustive work elsewhere. Of course these apparent agreements between the present study and other work do not necessarily prove anything. They may perhaps indicate that the method

of site classification adopted is not too bad, and that the values derived are at least relatively correct.

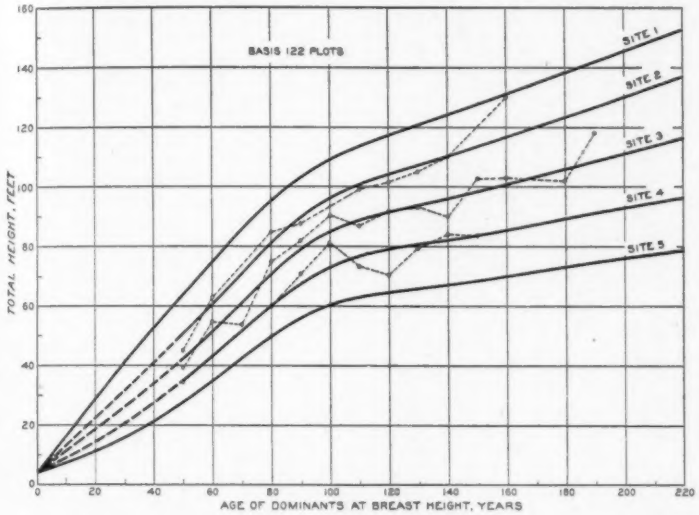

FIG. 3.—Heights of dominants on age

An attempt to check results by means of the "site factor" advocated by Hanzlik [5] in Oregon and Washington was not particularly satisfactory. Whereas he apparently found equal intervals between

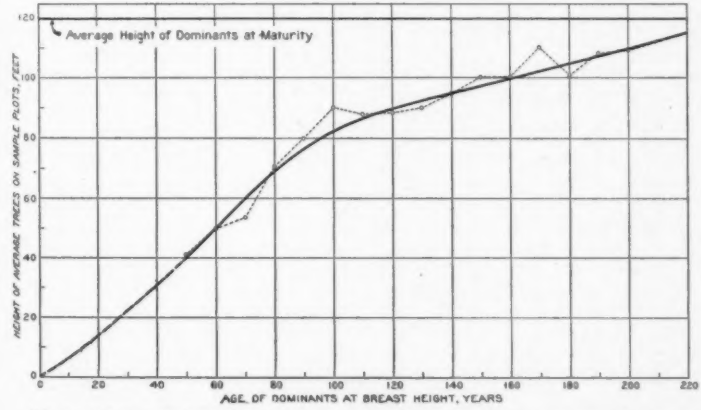
Average Height of Dominants at Maturity
HEIGHT OF AVERAGE TREES ON SAMPLE PLOTS, FEET
AGE OF DOMINANTS AT BREAST HEIGHT, YEARS

FIG. 4.—Relation of height of average trees to mature height of dominants on age of dominants

sites, figures in the present study show the factors varying in the same way as to yield, i. e., increasing from poor to good sites.

[5] HANZLIK, E. J. THE DETERMINATION OF SITE QUALITIES FOR EVEN-AGED STANDS BY MEANS OF A SITE FACTOR Proc. Soc. Amer. Foresters 9: 229-234. 1914.

As far as field application is concerned, the site factor method seems to have about the same deficiencies as the Baur method of site

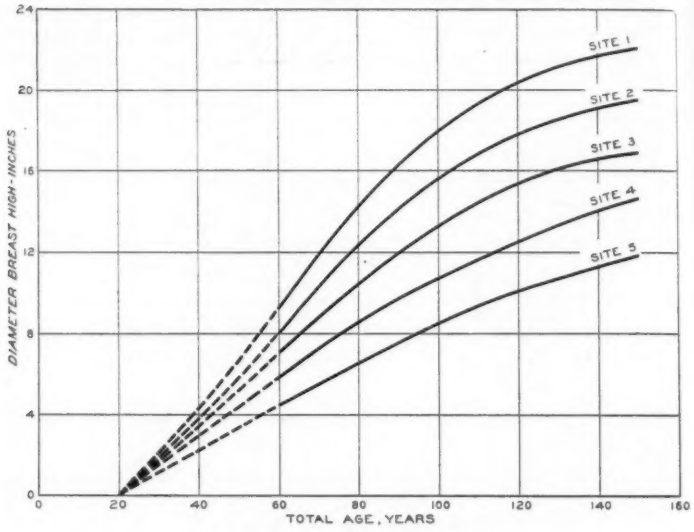

FIG. 5.—Diameter of average tree on age

determination; that is, both are primarily adapted to use in second-growth stands, and depend on measurement of plots for determination of either basal area per acre or volume per acre. In neither case is

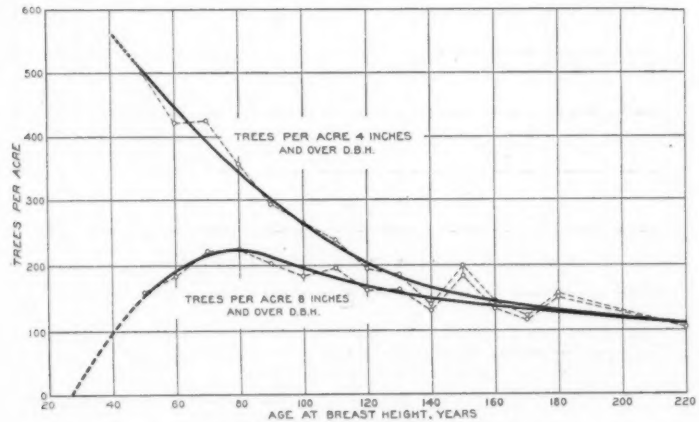

FIG. 6.—Average number of trees per acre on age

there any way of applying the results to areas of virgin forest, which seems to be the most important problem we have just now.

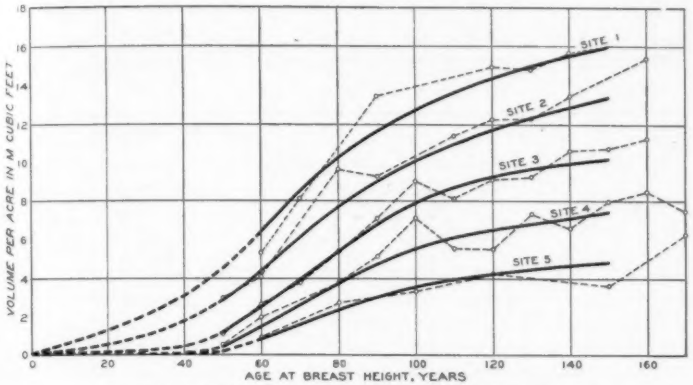

FIG. 7.—Yield in cubic feet per acre on age, bark included

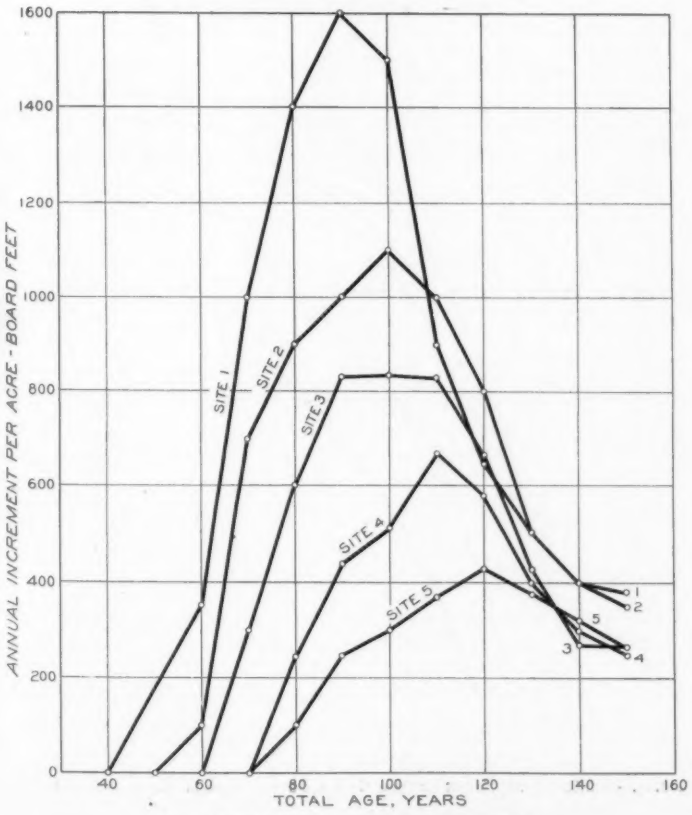

FIG. 8—Periodic annual increment per acre, board feet

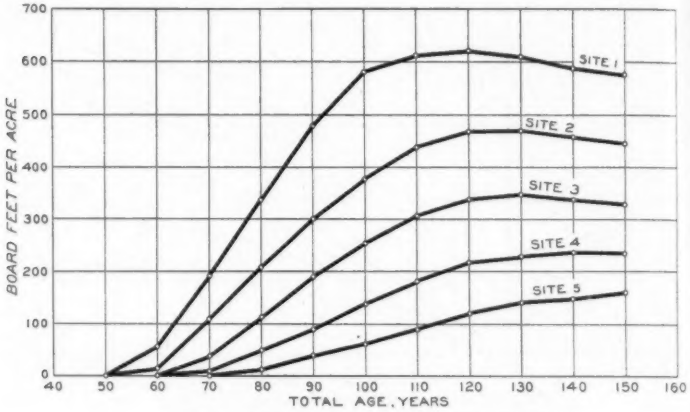

FIG. 9.—Mean annual increment per acre, board feet

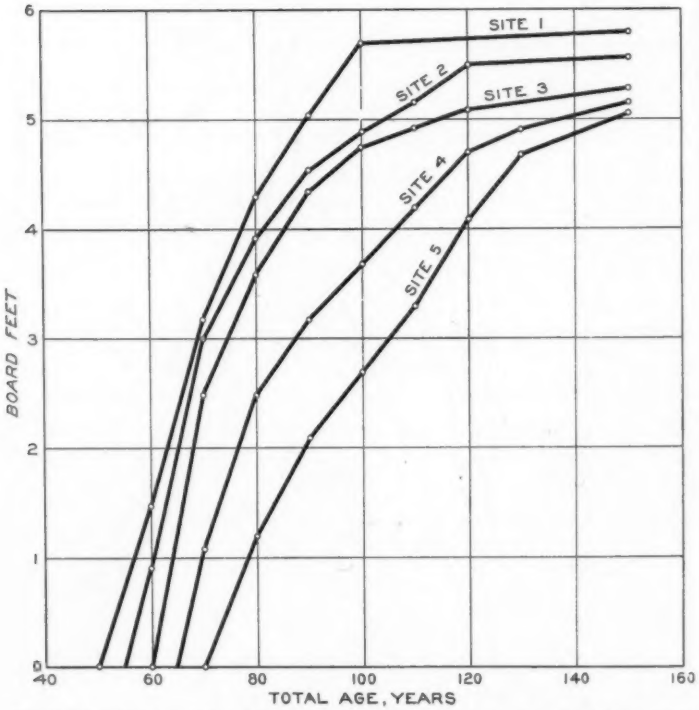

FIG. 10.—Board feet per cubic foot for the entire stand over 8 inches in diameter at breast height

DETERMINATION OF ROTATION

Various methods have been used for determination of rotation age and it is not the intention here to discuss these further. As a matter of pure silviculture the culmination of mean annual increment is probably the most generally recognized criterion. An examination of Figure 9 will show that mean annual increment reaches its highest point at an age of 120 to 130 years, after which it remains at practically the same level for 20 to 30 years before beginning to fall. The only excuse for extending the cutting age much beyond the culmination would be on the ground of quality increment, but where this is not important a rotation of 120 years at the outside is ample.

Figure 10, showing the board-foot cubic-foot ratio for the entire stand, also points to the conclusion that 120 years is about the proper cutting age. Up to that period in the stand's development on most of the sites the yield in board feet per cubic foot increases rapidly; beyond that point the yield is either practically constant or rises but slowly.

FACTORS OF CONSERVATISM

In the tables there are several elements which may be called factors of conservatism, which deserve discussion. The first of these is the allowance of 20 years for seedlings to reach breast height. As has already been explained, this will no doubt be lowered 5 to 10 years provided cutting is heavy, which will very likely result in a somewhat shortened rotation or a higher yield per acre on the same rotation of 120 years.

The second factor is the undoubted influence of the mature timber on the growth and yield of the plots. There is no way at present of measuring the influence of this factor, since practically no plots of the 50 and 60 year age classes were found within the virgin timber, whereas all of the true second growth measured was of those age classes. At any rate, the elimination of this factor will tend not so much to reduce the rotation as to increase the yield.

The third factor is the density of present stands. Within the next century thinning will undoubtedly come into effect and will tend to increase the yield. Still another element which may be very important is the fact that many stands which are now pure yellow pine will in the future be a mixture of pine and white fir, with probably higher yields per acre than from the pure pine. Here again it is very difficult to forecast just how much additional yield per acre a change in composition will make, but whatever the change, yields will undoubtedly be increased and the use of the present table will therefore give conservative estimates of the productive capacity of the entire area.

The application of the data in Table II to the stands obtained after cutting is a distinct problem which this study has not attempted to solve. The yields obtained on fully stocked small plots can not be expected over large areas, and reductions will be necessary in employing the table.

YIELD OF WHITE FIR STANDS

Although the data do not permit any positive conclusions regarding the yields of white fir stands under different conditions of age and site, the indications are (fig. 11) that on a given area of land white

fir attains a greater average mature height than yellow pine; and that consequently land is site 3 for white fir which for yellow pine is only site 4. This tentative conclusion further indicates that more wood per acre can be produced on a given area by white fir than by yellow pine.

The indication is, indeed, that for stands with the same average mature heights, white fir produces more wood per acre than yellow pine. This can readily be explained by the greater ability of white fir to endure shade, and consequently to tend toward a greater num-

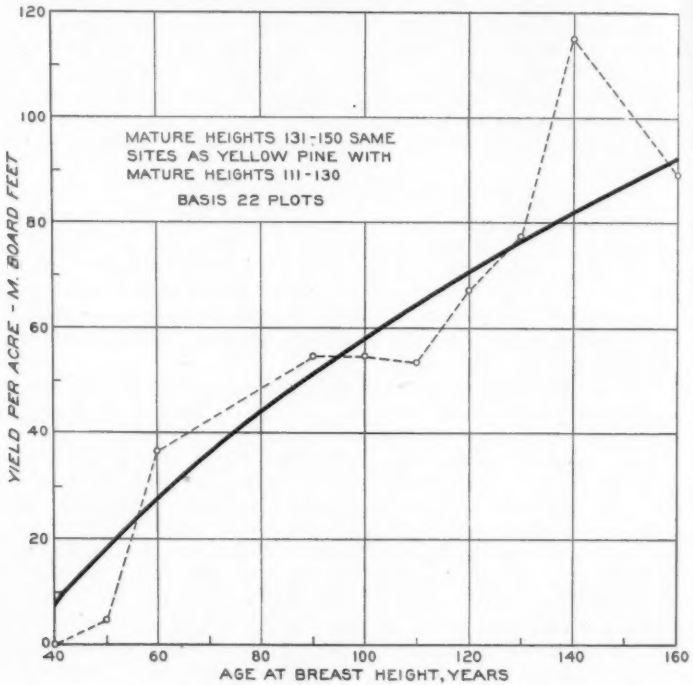

FIG. 11.—Yields per acre in white fir type

ber of trees per acre than yellow pine. It is thus probably true that white fir has decidedly the greater wood-producing capacity on a given piece of land. Whether future forest management shall favor pine or fir will depend primarily on the relative advantages of a high yield of less intrinsically valuable white fir and a lower yield of more valuable yellow pine.

SUMMARY

The present study indicates that on an average western yellow pine site, by preserving the young growth already on the ground under many of the virgin stands, a yield up to 40,000 board feet an acre can be obtained. This rate of growth is exceeded in several of

the western forest regions, but is probably higher than the yield in most of the subdivisions of the western yellow pine region. A rotation of about 120 years is indicated. However desirable shorter rotations may be, it does not appear that they can be realized and at the same time obtain the largest possible annual growth.

In the technique of the study several departures have been made from conventional practice. Of these perhaps the most important are (1) the use of dominant mature heights in the virgin forest as indices of site, (2) measurement of only a few heights on each plot, and construction of height-diameter curves for each as a basis for volume computations; (3) determination of ages by means of the increment borer; (4) employment of a log rule giving the actual merchantable contents of logs; and (5) adoption of standards of utilization not now in effect, but to be anticipated as effective when stands now young are utilized.

PRELIMINARY OBSERVATIONS ON AN INSECT OF THE COTTON STAINER GROUP NEW TO THE UNITED STATES[1]

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Assistant Entomologist, Southern Field-Crop Insect Investigations, Bureau of Entomology, United States Department of Agriculture

INTRODUCTION

During the past year *Dysdercus obscuratus* Distant,[2] an insect of the cotton stainer group not hitherto recorded in the United States, has been found in a number of cotton fields in the lower Rio Grande Valley of Texas, as well as in cotton fields in Tamaulipas, Mexico, on the opposite side of the Rio Grande. Although no injury of note has as yet been observed which can be attributed to the attacks of this insect, several closely related species have long been recognized as very serious cotton pests in different parts of the world. It was therefore considered advisable to obtain as much preliminary information as possible concerning the life history and habits of this species.

OBSERVATIONS ON DYSDERCUS OBSCURATUS AT BROWNSVILLE, TEX.

The first specimens of this species collected in the United States were found by the writer near Brownsville, Tex., in July, 1922. They were fairly numerous, and a note made at the time of collection stated that they "were common on grass and weeds near Brownsville." Although some were seen in cotton fields, they could be found more easily in a number of places quite distant from cotton, and the writer gained the impression that the species was mainly a nectar feeder. In June, 1923, H. C. Millender and F. F. Bibby, field inspectors for the Federal Horticultural Board, collected numerous specimens of the insect in cotton fields in the vicinity of Matamoros, Mexico. These collections first directed attention to the possible economic importance of the insect.

PRESENT KNOWN RANGE OF THE SPECIES IN AMERICA

From information furnished by W. L. McAtee, this insect has previously been collected from Central America and Mexico, in the following localities: San Geronimo, San Juan, Guatemala; Cache, Costa Rica; Atoyac in Vera Cruz, Teapa in Tabasco, Mexico. In addition, T. E. Holloway and the writer collected specimens at Victoria, Tamaulipas, Mexico, in March, 1922, and the writer has recently (November, 1923) collected specimens from Tampico, Tamaulipas.

It may be remarked that specimens of three additional species of the cotton stainer genus have been collected by the writer in the Brownsville section, namely, *Dysdercus concinnus* Stal, *D. mimus*

[1] Received for publication Apr. 27, 1925; issued December, 1925.
[2] Determined by W. L. McAtee, of the Bureau of Biological Survey, U. S. Department of Agriculture.

Say, and *D. obliquus* H.-S., according to determinations made by McAtee. None of these species, however, has appeared in cotton fields.

DISTRIBUTION IN THE RIO GRANDE VALLEY

The species is known to occur over an area extending from the Gulf westerly to Donna, Tex., or a little more than 60 miles, and from the Mexican border north to Lyford, Tex., a distance of about 45 miles. The known area of distribution therefore contains several hundred square miles, and it is probable that this area will be considerably extended by careful scouting.

In general, it can be seen that the insect occurs, perhaps continuously, from Central America, and probably farther south, along the Gulf Coast of Mexico to the lower Rio Grande Valley of Texas.

MANNER OF SPREAD

Little is known regarding the manner in which the insect occupies new territory. The present indications are that it has been present in the Rio Grande Valley for an indefinite period, although not collected until recently. The adults are fairly strong fliers, and probably the area of infestation is extended mainly by flight. The young stages are gregarious and move in groups from plant to plant, but their progress is slow and extension in this way is relatively unimportant.

FOOD PLANTS

At Brownsville, Tex., the species has been found feeding in numbers upon at least four wild plants. These include (1) the plant which is apparently its natural host, *Sida carpinifolia* L., a member of the mallow family; (2) the common ragweed, *Ambrosia artemisiaefolia;* (3) wormwood, *Ambrosia elatior* L.; and (4) one of the sunflower family, *Verbesina encelioides* (Cav.) B. and H. Close observation of all these hosts has failed to reveal marked injury to flowers or seeds, and it appears that the feeding is mainly confined to sucking up the nectar produced by the plants. The writer has never been able, in the case of any plant, to find a definite injury to the living tissue which could be attributed to the attacks of the insects.

In addition, adults have been observed in considerable numbers in many localities upon cotton plants. At Donna and Mercedes, Tex., inspectors of the Federal Horticultural Board report having observed considerable numbers of the immature stages in the cotton fields, but always in decayed bolls. As will be shown later, the very young stages subsist chiefly upon decaying vegetable material, or, perhaps more correctly, upon the juices which they can extract from this material. Adults have been observed in small numbers within the blossoms of many different plants, evidently in search of nectar.

POSSIBLE ECONOMIC IMPORTANCE

Whether the insect is economically important has not yet been definitely determined, although numbers have been observed and collected in cotton fields. The most valuable field observation yet made was contributed by T. C. Richardson, of Lyford, Tex., for

several years agent of the Department of Agriculture for the county of Cameron, Tex. Mr. Richardson reported that during the cotton-growing season of 1923 a machine which he was using in his cotton fields for catching boll weevils picked up more of these cotton stainers than any other kind of insect. At the same time he harvested a crop of 22 bales of cotton from 25 acres of land and no perceptible staining of the lint was observed. This would indicate that no particular damage was inflicted upon the cotton, despite the numbers of the insect present, and it also tends to confirm the theory that the species feeds mainly upon the secretions of the nectary glands.

Although immature stages of the insect have been observed feeding within decaying cotton bolls on the plants, the adults have never been seen attacking a living boll, and no indications of injury have been observed upon the plants. The adults evidently rove at will, and gather in considerable numbers upon many different plants, especially upon those which, like the cotton plant, flower continuously. These insects seem to be essentially nectar-feeding. However, the fact should not be lost sight of that there are several closely related species which are important enemies of cotton.

The cotton-growing industry of the Rio Grande Valley is increasing rapidly, thousands of additional acres, mostly on freshly cleared land, being planted annually. The area maintaining the native host plants of the stainer is therefore being continually reduced. This is probably one of the main reasons for the sudden appearance of the insect in the cotton fields, vast numbers being forced to seek new food plants and new breeding territory. It is distinctly possible, therefore, that as this process is continued other host plants may be attacked. Since the genus in general has shown a marked preference for plants of the order Malvaceae, and since the natural host plants are being so largely displaced by the wholesale planting of cotton, it is reasonable to assume that the insects will be gradually driven into the cotton fields.

POSSIBILITY OF FUTURE SPREAD

With the information now available, the future advance of this insect can be only conjectural. The species has not yet been found beyond the limits of its main host plant, *Sida carpinifolia*. According to present information, its occurrence upon cotton and other plants of economic importance can be considered as more or less incidental to the wandering of the individuals in search of food. Unless the species should definitely transfer its breeding habits to other plants of economic importance, it now appears probable that its distribution will be mainly coincidental with the territory occupied by its principal host plant, but no definite prediction can be made.

STUDIES OF THE LIFE HISTORY OF THE INSECT

At the outset of work on the life history of the insect it was found difficult to rear the nymphs through the adult stage. After seven types of rearing cages had been tested and conditions gradually adapted to the requirements of the insects, much better results were obtained. Mating cages can now be stocked from the supply of insectary-reared adults. This could not be done when it was necessary to rely for breeding material on adults collected in the field.

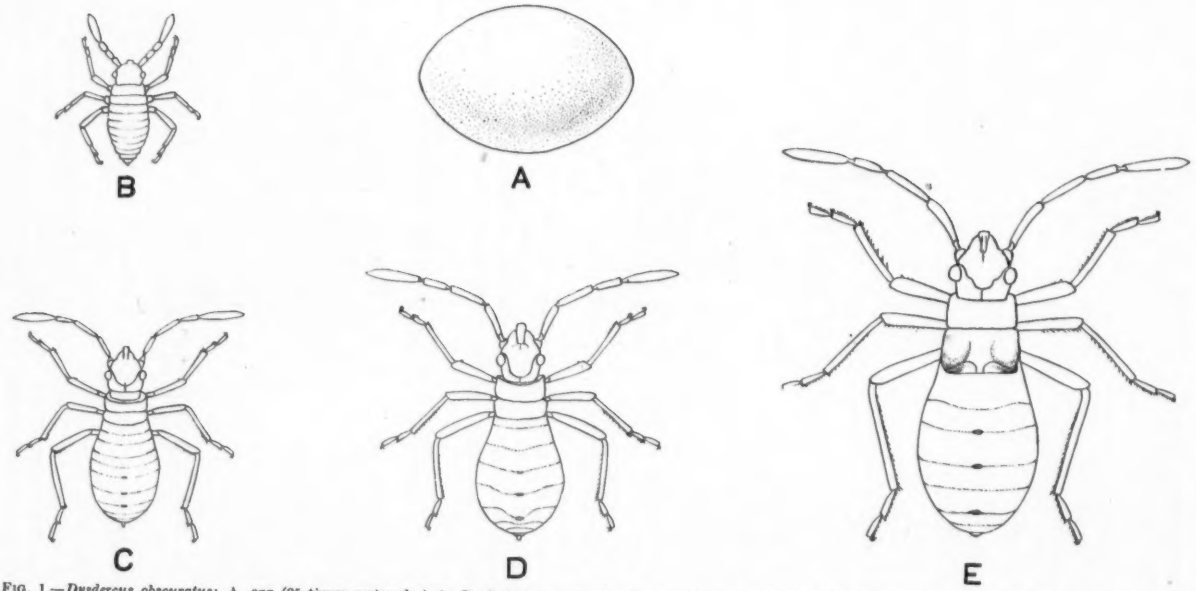

FIG. 1.—*Dysdercus obscuratus:* A, egg (25 times natural size); B, first-stage nymph; C, second-stage nymph; D, third-stage nymph; E, fourth-stage nymph (all drawings of nymphs 9 times natural size)

The type of rearing cage finally adopted consisted of large lantern globes, covered with cheesecloth on top, and with their bases inserted about 1 inch in soil in large trays. This soil was kept constantly moist. The host plants provided were planted in the soil and additional fruiting capsules were introduced into the cages when required for oviposition. This type of cage therefore provided a growing host plant, plenty of moist soil, and good ventilation through the cheesecloth cover. Moreover, in searching for eggs, the area of search was confined to the space covered by the base of the globe, or a circle about 4 inches in diameter, greatly simplifying the task of finding them.

All rearing was done on *Sida carpinifolia*, the native host plant of the insect, but present plans include a series of rearing tests on cotton.

NUMBER OF STAGES

It has been found that there are seven stages in the development of the insect. These include the egg, five nymphal stages, and the adult stage.

THE EGG

The eggs look very much like microscopic hens' eggs (fig. 1, A), being of about the same shape and similar in general proportions. They are about one twenty-fifth of an inch in length, and their greatest width, which is not exactly at the center of the egg, but slightly toward one end, is about two-thirds the length. When first deposited, the eggs are shiny, pearly-white, and semitransparent. As the incubation progresses they gradually turn a faint pink, and at the time of hatching are a light pinkish brown.

DURATION OF THE EGG STAGE

Up to the present 26 more or less exact incubation records have been obtained in the cages. It is difficult to make the incubation records with perfect accuracy owing to the female's habit of placing the egg under the surface of the ground, which sometimes results in the egg being overlooked until the second day. This probably occurred in two cases of the 26 considered, since one record of three days and one of four appeared too short in comparison with the average incubation period observed.

The 26 incubation records gave an average incubation period of 7.85 days. It should be taken into consideration, however, that life-history observations were not begun until after midsummer, and that a large proportion of these records were not secured until after cooler weather had arrived. In July and August, 5 records of 5 days each were obtained, as well as the two shorter records mentioned above. In September and October, 6 records of 6 days each were obtained, as well as 4 of 7 days, and several records of longer periods. On the other hand, in November and December the shortest incubation period recorded was 12 days, and the longest 17 days. Evidently the incubation period is about 5 days in midsummer and lengthens very considerably as the weather becomes cooler.

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FIRST-STAGE NYMPH

The nymphs of the first stage are of about the same color as the nearly hatched eggs, a very light brown, with a pinkish tinge. They are a little larger than the eggs and slightly more elongate, and the legs and antennae are threadlike and colorless (fig. 1, B). It may be remarked that the head of the embryo nymph develops within the long-pointed end of the egg, and that the general contour of the body after hatching much resembles the shape of the egg. This stage is spent entirely underground, the nymph evidently feeding upon the supply of decaying food usually provided by the adult female at the time of oviposition.

Duration of the First Stage

Twenty-one records of the duration of the first stage have been secured in the insectary. These cover a total of 132 days and give an average period of 6.29 days for this stage. As was the case with the incubation records, however, as well as with all subsequent records to be considered, cool weather undoubtedly resulted in the prolongation of many of them, so that the average secured is probably rather longer than the correct annual average. Since 8 records of 3 days were secured during the warm months of August, September, and early October, as well as 4 additional records of 4 days each, it seems evident that the midsummer period of the first stage is about 3 days. The longest record obtained was 19 days, from December 10 to December 29, 1923, but only 3 additional records were secured, each of 10 days or more.

SECOND-STAGE NYMPH

The nymphs of the second stage are about twice the size of those of the first stage. After the first molt the light color of the first stage is lost, and the nymphs of the second stage emerge bright red in color, slightly paler on the abdominal surface. The general shape of the insect can now be plainly distinguished, since it has attained a length of about one-eighth of an inch (fig. 1, C). The legs and antennae are now much longer and stronger, and in this stage the nymph is very active, being able to run about rapidly. Second-stage nymphs are sometimes, though rarely, seen above the surface of the ground, but usually, as in the case of the first stage, this stage is spent below the surface.

Duration of the Second Stage

Thirteen records of the second-stage nymphs have been secured, occupying a total of 109 days, thus giving an average period of 8.39 days. Four days are evidently the average midsummer duration of this stage, since four records of this length were secured in the warmer weather. The longest record covered 18 days, from December 11 to December 29, 1923.

THIRD-STAGE NYMPH

In the third stage the insect is about twice as large as in the second stage, and resembles it closely except in size (fig. 1, D). The color is still an even, bright red, but the head, thorax, and abdomen can now be seen to be divided by very faint whitish lines. This stage

is also very active and is usually the smallest stage to be found upon the plants under field conditions. The nymphs of the third stage, as well as the few nymphs of the second stage which have been observed above the ground, have a habit of dropping to the ground when the plant is disturbed and quickly hiding themselves in crevices in the soil. For this reason it is very difficult to collect them in numbers.

Duration of the Third Stage

Nine records of the third stage have been obtained, the period varying from 4 to 18 days. The total time covered by the nine records was 85 days, giving an average period of 9.44 days.

FOURTH-STAGE NYMPH

The nymph of the fourth stage is decidedly larger than that of the third, the insect now having attained a length of slightly more than one-fourth of an inch, exclusive of the antennae, which are about half as long as the body (fig. 1, E). Although the general color of the body is still bright red, the segmentation is now distinctly marked by delicate white lines on the dorsal surface. The abdominal surface is much paler than the dorsal, and the segments are joined by bright red lines. The wing pads now appear for the first time as two heavy black spots at the rear end of the thorax, and the legs and antennae are almost black. The nymphs of this stage are rather numerous in the field and can be collected without difficulty, since they are not nearly so shy as those of the third stage.

Duration of the Fourth Stage

Eleven records of the fourth stage cover a total of 110 days, and give a general average period of 10 days. These periods range from 4 to 19 days. Evidently the midsummer average period is about 4 or 5 days for this stage.

FIFTH-STAGE NYMPH

In the fifth stage the sexes differ considerably; so much so that at first they were thought to be two separate stages. The female nymph of the fifth stage is considerably larger than the male nymph of the same stage owing to the much larger abdomen, which makes the wing pads appear proportionately shorter. The fifth-stage male nymph resembles the adult much more closely than does the female, since the abdomen is not so large and the wing pads therefore lie flat along the back, appearing to be longer in proportion to the size of the abdomen (fig. 2, A).

The length of the body in the fifth stage averages about three-eighths of an inch, exclusive of the antennæ. The wing pads are now about twice as large as they were in the fourth stage. The general coloration is much the same as before except that the segments of the body are very distinct, the dividing lines having become much more prominent.

Duration of the Fifth Stage

All of the preceding records of the insect, from the incubation of the egg to the fourth-stage nymph, have been based upon mass observations, all the individuals present in one cage being utilized

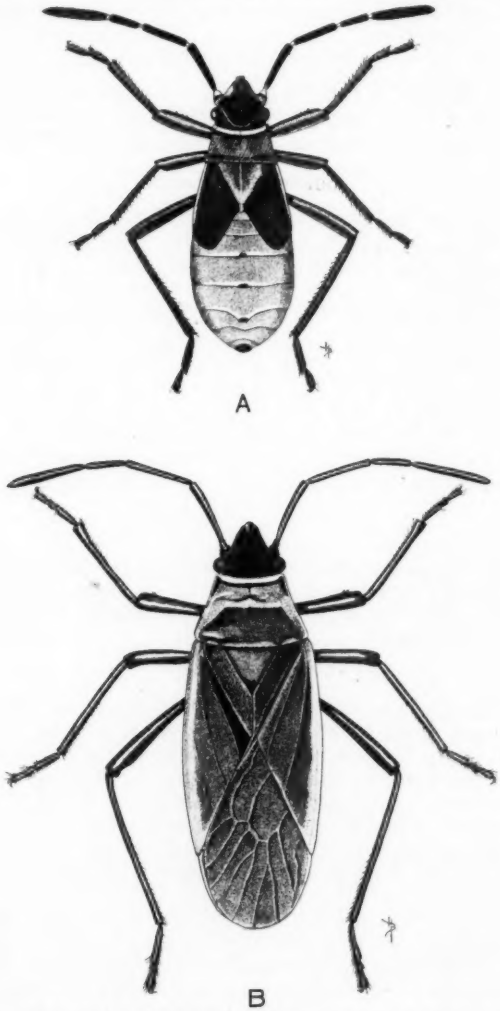

Fig. 2.—*Dysdercus obscuratus*. A, Fifth-stage nymph; B, adult. × 6

to make one record. A single record is therefore based upon the development of possibly a considerable number of individuals. In the case of the fifth-stage nymph, however, the number of specimens which were carried successfully through their entire life history, from

egg to adult, was only 31. These 31 records are therefore considered individually.

The total length of time occupied by these 31 fifth-stage records was 564 days, giving an individual average of 18.2 days each. The individual variation was from 10 to 29 days. Since, however, the first adult reared from the egg in the cages appeared on October 7, 1923, and all of the remainder were reared during the months of October, November, and December, 1923, it is evident that their life-history periods were longer than they would have been during the hotter months of midsummer.

TOTAL PERIOD OF DEVELOPMENT

From the data presented it is apparent that great variation exists between the total length of time required for development during the months of midsummer and those of fall and winter when the periods of development are considerably extended because of lower temperatures. Table I shows this more clearly, and presents the information in a more concise form.

TABLE I.—*Developmental periods of Dysdercus obscuratus at different seasons*

Stage	Midsummer period	Fall period	Winter period	Total number of records	Total number of days	Average period of development
	Days	*Days*	*Days*			*Days*
Incubation	5	8	12 to 17	26		7.85
First stage	3	5	10 to 13	21	132	6.29
Second stage	4	6	11 to 13	13	109	8.39
Third stage	5	9	15 to 18	9	85	9.44
Fourth stage	5	7	15 to 19	11	110	10.00
Fifth stage	10	20	24 to 28	31	564	18.20
Total development	32	55	87 to 108	111	1,000	60.17

THE ADULT

The adults are brightly colored, slightly more than one-half inch in length, the antennae adding to this about three-eighths of an inch (fig. 2, B). The head is coral red, with a narrow white band between the head and thorax. The thorax contains a transverse band of coral red, followed by a narrow yellow band, with a transverse black ridge at the base of the wings. The predominating colors of the wings are black and yellow, with faint white margins. The coloration of the wings varies considerably, irrespective of sex, some adults having much more yellow than black, others having nearly black wings with little yellow showing. The legs and antennæ are orange at the base, with black extremities. The abdomen is bright red dorsally, with white lines between the segments. Ventrally the abdomen is white with a bluish tinge, and has bright red lines between the segments.

It is rather difficult to distinguish the sexes from each other. Usually the female is slightly larger than the male, and the abdomen is larger and stouter. The most easily distinguished sexual character is the wider red bands across the ventral surface of the abdomen of the male, particularly the last three segments.

Longevity of the Adult

Only eight complete longevity records have been secured from observations in the mating cages, four of these being for females and four for males. The four females lived a total of 199 days, giving an average female longevity of 49.8 days. The four males lived a total of 193 days, giving an average male longevity of 48.25 days. The maximum individual longevity of the females was 55 days; the maximum male longevity 73 days. Although little difference between the longevity of the sexes is shown above, there are indications that on an average the females are longer-lived than the males. The survival of 37 field-collected females in the mating cages gave an average survival of 10.92 days from the date of collection. Thirty-six males lived an average of 9 days. Of course no data were available showing the ages of these adults at the time of collection.

HABITS OF THE SPECIES

The adults are gregarious, not only in regard to each other but also in regard to the larger stages of the immature forms. They are commonly found in groups on the plants from which they derive their nourishment, the groups including both sexes of the adult and frequently considerable numbers of nymphs of the third, fourth, and fifth stages; sometimes, but very rarely, nymphs of the second stage. These groups move about from plant to plant, keeping more or less together, the extent of their movements apparently being controlled by the quantity of food which they are able to find. Frequently great numbers of the insects concentrate upon a certain group of plants which are evidently supplied with large quantities of the sought-for juices, and possibly hundreds of the insects will be found upon the plants for several days, after which, having apparently exhausted the food supply, they migrate to other plants in the neighborhood. The plants which have been "worked over" do not appear to be damaged to any appreciable extent by the wholesale visitation, although stalks have several times been observed so weighted with the insects that they have been bent nearly to the ground.

Mating appears to occur at any time after the adults have reached the age of 2 days. The eggs are generally deposited under the surface of the ground, a dead leaf or fruiting capsule of the host plant usually being buried with them for food for the nymphs after hatching. When no leaf or fallen capsule is available, the females sometimes oviposit in the soil immediately around the stem of the host plant where it emerges from the ground. Occasionally a simple groove in the ground is used for oviposition. Eggs may occur singly or in clusters of from 2 to 25 or 30, adhering together very slightly, although easily separable without damage. The act of oviposition has been observed on two or three occasions. When a suitable capsule had been selected, the female would deposit two or three eggs, then carefully cover them with soil, pulling the particles over them with her feet. More eggs would then be deposited and covered in their turn, until finally the entire capsule would be buried under the surface. These observations were all made under insectary conditions, since

the closest search has as yet failed to disclose eggs in the field under natural conditions.

From the manner of oviposition, it is very difficult to determine the exact number of eggs deposited. Although a considerable number of eggs were secured in cages containing no soil, there did not appear to be as many per female as there should have been, and it is probable that oviposition was curtailed by unnatural conditions. The greatest number of eggs definitely counted from two females was 107, laid on two consecutive nights (56 eggs on the night of July 26–27 and 51 eggs on the night of July 27–28). No eggs were subsequently deposited, so that the eggs, in this case, averaged 53.5 per female. Usually, however, only about 15 to 30 eggs were obtained from each female in this type of cage. It has not been possible to make definite counts of eggs deposited underground in the cages containing soil.

SUMMARY

During the past year *Dysdercus obscuratus* Distant, an insect of the cotton stainer group new to the United States, has been found in cotton fields in Texas.

The insect occurs, perhaps continuously, from Central America, and probably farther south, along the Gulf Coast of Mexico to the lower Rio Grande Valley of Texas.

Probably the area of infestation is extended mainly by flight.

At Brownsville, Tex., the species feeds upon four wild plants, *Sida carpinifolia* L., the common ragweed (*Ambrosia artemisiaefolia*), wormwood (*Ambrosia elatior* L.), and *Verbesina encelioides* (Cav.) B. and H.

Whether the insect is economically important has not been definitely determined.

The eggs are deposited in clusters, usually under the surface of the ground. The incubation period is about five days in midsummer.

The nymph has five stages. The duration of each stage varies with the time of year in which it occurs.

In the lower Rio Grande Valley the average period of development from egg deposition to the appearance of the adult insect was found to average 32 days in midsummer, 55 days in the fall, and to range from 87 to 108 days in the winter.

Male adults in cages were found to live an average of 48.25 days; females in cages lived an average of 49.8 days.

The adults and larger instars of the nymph stage are gregarious, being found commonly in groups on the plants from which they derive nourishment. These groups move about from plant to plant. Frequently great numbers of insects will concentrate upon a certain group of plants and remain there for several days.

NITROGEN METABOLISM IN ETIOLATED CORN SEEDLINGS [1]

By S. L. JODIDI

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INTRODUCTION

The process of seed germination is of great significance as a means of attaining deeper and more extensive knowledge concerning the physiology of plants. The universal importance of cereals as food and feed has made it desirable to take up a systematic study of these plants with the object of throwing additional light on the fundamental physiological and biochemical processes involved in the germination of various cereal seeds. Because of the vast field covered by the phenomena in question it was necessary to limit the scope of the investigation, and the work has therefore been confined chiefly to the study of the nitrogenous compounds (proteins and nonproteins) in cereals. Some interesting studies (*14*, *16*) of these compounds in relation to the nutrition of man and animals have been made.

Before the germination work proper was taken up, preliminary experiments showed that wheat (*Triticum vulgare*) (*9*), [2] oats (*Avena sativa*) (*10*), corn (*Zea mays*) (*11*), and rye (*Secale cereale*) (*12*) contain polypeptides and free amino acids in their ungerminated kernels.

There is a great deal of information at hand concerning the process of germination. In some seedlings the proportions of acid amides and amino acids are fairly uniform at certain stages of germination; at other stages the acid amides prevail. Some seedlings, like those of grasses and legumes, are rich in asparagine; the seedlings of others, like spinach and black radish, are rich in glutamine; and the seedlings of still others, like the sunflower and pumpkin, contain both asparagine and glutamine, though one of them ordinarily in predominant proportion (*18*). As to the interrelationship and significance of these facts we do not know much beyond the hypothesis of Schulze, that during germination the amino acids are gradually converted into asparagine or glutamine (*17*).

So far as the occurrence of polypeptides in seedlings is concerned, we have no information whatever, nor do we have sufficient knowledge with regard to the humin bodies met with in seedlings.

It is well known that plant proteins may be split by chemical means (acids, alkalies), by bacteria, and by enzymes naturally occur-

[1] Received for publication June 22, 1925; issued December, 1925. Thanks are due to E. H. Toole, of the seed-testing laboratory, Bureau of Plant Industry, for valuable suggestions and for assistance with materials and apparatus.

[2] Reference is made by number (italic) to "Literature cited," p. 1163.

ring in plant tissues. Whereas hydrolysis of plant proteins with strong acids leads to amino acids, bacterial action when long enough continued leads to secondary products (fatty acids, amines) through deamination and decarboxylation. On the other hand, proteolysis under the influence of enzymes ordinarily present in seeds, seedlings, and generally in various plant tissues yields not only amino acids, but also asparagine and glutamine, instead of aspartic and glutaminic acids, which are obtained by acid hydrolysis. Whether asparagine and glutamine are formed secondarily from amino acids as advanced by Schulze (*17*) needs further confirmation. It is, therefore, not surprising that studies on the physiological processes which take place during seed germination, involving as they do catabolism of the nitrogenous seed compounds on the one hand and anabolism of new nitrogen compounds in the growing parts of the seedling on the other are very far from being complete. Nearly every investigator emphasizes the necessity of further studies of the physiological processes in question. Thus Brown and Morris (*2*) state:

> The complex metabolic processes which take place during the germination of seeds have attracted, from the time of Th. De Saussure, a large amount of attention * * * nevertheless at the present time we are far from possessing an exact knowledge. * * *

Toole (*21*), says:

> Although the volume of literature on seed germination is large, knowledge of the transformations which occur in the seed and seedling during germination is far from complete. Also, the data on the influence of specific external factors on germination are confusing. * * *

In the study of seed germination herein reported etiolated corn seedlings only have been used. There is probably, during the first stage of germination, no essential difference between seedlings grown in the presence of light and those grown in its absence. As soon, however, as chlorophyll develops in the seedlings there is, along with the degradation of the seed proteins, which are so well known through the excellent work of Osborne (*13, 14, 15*) Chittenden (*3*), and their collaborators, considerable accumulation of carbohydrates in the seedlings by photosynthesis, which renders the estimation and isolation of the various nitrogenous disintegration products very difficult, and hence not quite accurate. On the other hand, etiolated seedlings ordinarily use up the seed carbohydrates from which they derive the continual supply of energy necessary for vital activities. The nitrogen compounds in such seedlings, therefore, become gradually more concentrated.

METHODS

In order to obtain comparable results, the writer tried to maintain as uniform conditions as possible throughout this work. Thus, he used for his experiments the same variety of corn (Four County corn), which was bred by the Four County Grain Improvement Association at Ackley, Iowa, under the direction of the Iowa Agricultural Experiment Station. The seed was planted on perforated copper trays fairly uniformly, about 400 kernels per tray, between moist absorbent paper towels, and kept in a dark room at the constant temperature of 25° C. for the desired period. Only occasionally the temperature would rise to 26° or 27°. No watering whatever

was done, the moisture within the germinator being maintained by a pan filled with water and placed at the bottom of the germinator. A small portion of the seed, to be mentioned subsequently, was planted in pots filled with sand which was thoroughly washed and contained but a negligible quantity of nitrogen. This seed, too, was placed in a dark room at the temperature of 27° C.

Tests with three samples of seed planted in sand at the temperature of 27° C. gave 93, 93, and 95 per cent germination. Two other samples in which the seed was put between moist absorbent paper towels and kept at 30° C. gave 95 and 90 per cent germination, thus proving the high quality of the seed.

One difficulty encountered in the work was the molding of the seedlings. Whereas seedlings which were allowed to grow from two to four days were practically free from mold, those which grew for a longer period were more or less covered by a growth of fungi, among which *Rhizopus nigricans* was conspicuous. In an attempt to do away with the fungi the corn seed was treated with a 0.25 per cent solution of uspulun (a chlorophenol mercury compound) for 30 minutes, at the expiration of which the seed was washed with water and immediately planted with the aid of an uspulun-treated spatula. This treatment, although helpful to a certain extent, did not obviate the difficulties entirely. Nor could the appearance of fungi be prevented by spraying with mercuric chloride solution (1 : 1,000). Whether untreated or uspulun-treated seed was allowed to germinate, in each case only material free from mold was taken for work. The seedlings, including the seed, were dried in an electric drying oven at 60° C. for from two to three days, after which they were ground in a mill until all had passed through a 40-mesh sieve, and put into jars ready for use.

The total nitrogen was estimated by the Gunning modification of the Kjeldahl method.

The protein nitrogen was determined according to Stutzer's method as outlined in previous publications (*6*, *7*, *8*).

The nonprotein nitrogen was estimated by determining the nitrogen in the filtrate from the protein precipitate, as obtained by means of Stutzer's copper solution (*20*), or it was calculated by difference from a hundred.

The methods for estimation of acid amides, amino acids, polypeptides and other constituents will subsequently be described in this paper.

The results secured are recorded in the following tables.

EXPERIMENTAL DATA

An examination of Table I shows that the protein nitrogen fell rapidly with the progress of germination. Thus, from 95.68 per cent in the ungerminated seed, calculated on the basis of the total nitrogen, it fell to 77.63, 60.74, 61.95, and 57.36 per cent after 2, 4, 5, and 8 days, respectively, in the untreated seedlings with the paper substratum. Similarly, in the uspulun-treated seedlings the protein nitrogen decreased to 61.07, 54.52, and 55.26 per cent after 4, 5, and 8 days, respectively. That the protein nitrogen fell very rapidly from 95.68 per cent in the seed to 58.02 per cent in the seedlings which were grown in sand for but 3 days may be attributed to the considerably higher moisture conditions of the sand seedlings.

TABLE I.—*Proportion of total, of protein, and of nonprotein nitrogen in the various seedlings*

No.	Conditions of germination				Total nitrogen on the basis of—		Protein nitrogen on the basis of—		Nonprotein nitrogen			
									By direct determination on the basis of—		By difference from 100 on the basis of—	
	Duration	Substratum	Temperature	Treatment	Oven-dried seedlings	Original oven-dried seed	Oven-dried seedlings	Total nitrogen	Oven-dried seedlings	Total nitrogen	Oven-dried seedlings	Total nitrogen
	Days		*° C.*		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	3	Sand	27	None	1.75	.....	0.97	56.78	.....	.....	0.74	43.22
2	3	do	27	do	1.69	.....	1.01	59.26	0.69	40.60	.70	40.74
3	3	do	27	do	1.69	.....	.....	.....	.....	.....	.....	.....
		Average	.....	.....	1.71	.....	.99	58.02	.69	40.60	.72	41.98
4	4	Sand	27	None	1.86	.....	.....	.....	.....	.....	.....	.....
5	4	do	27	do	1.90	.....	.....	.....	.....	.....	.....	.....
		Average	.....	.....	1.88	.....	.....	.....	.....	.....	.....	.....
6	2	Paper	30	None	1.77	1.71	1.36	79.33	.37	21.53	.36	20.67
7	2	do	30	do	1.71	1.65	1.31	75.93	.49	28.33	.41	24.07
8	2	do	30	do	1.69	1.63	.....	.....	.....	.....	.....	.....
		Average	.....	.....	1.72	1.66	1.33	77.63	.43	24.93	.38	22.37
9	4	Paper	30	None	1.76	1.63	1.08	58.80	.....	.....	.75	41.20
10	4	do	30	do	1.89	1.74	1.15	62.68	.72	39.63	.68	37.32
11	4	do	30	do	1.87	1.73	.....	.....	.....	.....	.....	.....
12	4	do	30	do	1.79	1.65	.....	.....	.....	.....	.....	.....
		Average	.....	.....	1.83	1.69	1.12	60.74	.72	39.63	.72	39.26
13	5	Paper	25	None	1.80	1.61	1.11	61.45	.69	38.20	.69	38.55
14	5	do	25	do	1.80	1.61	1.12	62.45	.67	37.10	.68	37.55
		Average	.....	.....	1.80	1.61	1.12	61.95	.68	37.65	.69	38.05
15	8	Paper	30	None	2.10	1.73	1.16	55.38	1.01	48.09	.93	44.62
							1.19	57.06	.92	44.23	.90	42.94
16	8	do	30	do	2.11	1.74	1.24	59.12	.92	44.16	.85	40.88
17	8	do	30	do	2.06	1.70	1.21	57.88	.93	44.37	.88	42.12
		Average	.....	.....	2.09	1.72	1.20	57.36	.95	45.21	.89	42.64
18	4	Paper	25	Uspulun	1.78	1.65	1.13	63.34	.65	36.50	.67	36.66
19	4	do	25	do	1.78	1.65	1.05	58.80	.73	41.00	.75	41.20
		Average	.....	.....	1.78	1.65	1.09	61.07	.69	38.75	.71	38.93
20	5	Paper	25	Uspulun	1.85	1.66	.96	52.11	.88	48.01	.88	47.89
21	5	do	25	do	1.83	1.65	1.05	56.92	.....	.....	.79	43.08
		Average	.....	.....	1.84	1.66	1.01	54.52	.88	48.01	.84	45.48
22	8	Paper	25	Uspulun	1.83	1.54	1.02	56.24	.82	44.93	.80	43.76
23	8	do	25	do	1.81	1.53	.99	54.27	.89	49.11	.83	45.73
		Average	.....	.....	1.82	1.54	1.01	55.26	.86	47.02	.82	44.74
24	11	Paper	25	Uspulun	1.96	.....	1.06	55.28	.82	42.92	.85	44.72
25	11	do	25	do	1.86	.....	1.12	58.78	.....	.....	.79	41.22
		Average	.....	.....	1.91	.....	1.09	57.03	.82	42.92	.82	42.97
26	15	Paper	25	Uspulun	1.93	.....	1.04	56.14	.82	44.10	.81	43.86
27	15	do	25	do	1.77	.....	1.04	55.98	.82	44.18	.81	44.02
		Average	.....	.....	1.85	.....	1.04	56.06	.82	44.14	.81	43.94
28	.....	Ungerminated seed	.....	.....	1.73	.....	1.64	95.72	.07	4.21	.07	4.28
29	.....	do	.....	.....	1.71	.....	.....	95.64	.08	4.41	.07	4.36
		Average	.....	.....	1.72	.....	1.64	95.68	.08	4.31	.07	4.32

Beginning with the eighth day and continuing to the fifteenth there was a slight increase in the protein nitrogen. There would seem to be an effort on the part of the etiolated seedlings to synthesize proteins. For this process they needed energy, which, in the absence of light, they derived from breaking down the reserve materials of the seed, such as the starch.

The figures for the nonprotein nitrogen, found by direct estimation, quite naturally stand in reverse ratio to the protein nitrogen. Thus, the ungerminated seed (Nos. 28 and 29) with the highest protein nitrogen (95.68 per cent) has the lowest nonprotein nitrogen (4.31 per cent). Equally, the five-day uspulun-treated seedlings (Nos. 20 and 21) with the lowest protein nitrogen (54.52 per cent) have the highest nonprotein nitrogen (48.01 per cent).

The percentage of total nitrogen, it will be noticed, increases somewhat with the duration of germination, when calculated on the basis of the oven-dried seedlings. In this connection it should be remembered that the whole of the seedlings, including the seed, was taken into the work. Therefore, strictly speaking, the total nitrogen of the seedlings should be equal to the total nitrogen of the seed, provided the weight of the seedlings (including the unutilized seed) at any time would be equal to that of the ungerminated seed. Actually, however, the weight of the former decreases more and more as germination progresses, because the seedlings, in the absence of light, derive the energy necessary for growth, respiration, and other vital activities from oxidation or cleavage of the stored-up materials. If only nonnitrogenous compounds such as starch were utilized for the creation of energy, then the total nitrogen calculated on the basis of the oven-dried seedlings should, with the progress of germination, gradually become greater than the nitrogen proportion in the ungerminated seed. However, the growing seedlings can and do obtain the necessary energy also by the cleavage and further degradation of nitrogenous compounds such as proteins, as is evident from the observation on proteolytic anzymes reported subsequently. Since this decomposition may be accompanied by loss of nitrogen, it has the tendency to decrease the proportion of nitrogen in the seedlings. It is for these reasons that the total nitrogen was calculated to the oven-dried seedlings as well as to the seed. The circumstance that the total nitrogen calculated on the seedlings is higher than in the ungerminated seed is an indication that the growing seedlings derive the necessary energy chiefly at the expense of the nonnitrogenous compounds, such as starch. This is also corroborated by the observation that the aqueous extracts of the seedlings contained less starch the further the germination progressed.

In order to recalculate the nitrogen found directly in the seedlings to the oven-dried seed, experiments were made to ascertain the change of weight of the seed on germination. Each of several perforated copper trays was covered with absorbent paper towels and divided into equal parallel sections. On each of these there were planted 10 uniform-looking corn kernels, the weight of which was accurately determined. On covering the seed with absorbent paper, the whole was thoroughly sprinkled with water and allowed to germinate in a dark room under exactly the same conditions as described above. After the expiration of 2, 4, and more days, all of the seed-

lings of the clean-looking rows were weighed, then dried to constant weight at 105° C. and weighed again. The results are recorded in Table II.

TABLE II.—*Change of weight in the various seedlings during germination*

No.	Conditions of germination				Weight of ungerminated seed (10 kernels)		Weight of oven-dried seedlings	Ungerminated oven-dried seed
	Duration	Substratum	Temperature	Treatment	Air-dry	Oven-dried		
	Days		*° C.*		*Grams*	*Grams*	*Grams*	*Per cent*
1	2	Paper	25	None	3.8200	3.6080	3.4914	96.77
2	2	do	25	do	3.7408	3.5332	3.4088	96.48
		Average						96.63
3	4	Paper	25	None	3.7200	3.5135	3.2460	92.39
4	4	do	25	do	3.6784	3.4742	3.2034	92.21
		Average						92.30
5	5	Paper	25	None	3.9100	3.6930	3.2746	88.67
6	5	do	25	do	3.9637	3.7437	3.3631	89.83
		Average						89.25
7	8	Paper	25	None	3.6916	3.4867	2.8093	80.57
8	8	do	25	do	3.8727	3.6578	3.0856	84.36
		Average						82.47
9	2	Paper	25	Uspulun	3.9900	3.7686	3.6281	96.27
10	4	do	25	do	3.7891	3.5788	3.3104	92.50
11	5	do	25	do	3.4386	3.2478	2.9208	89.93
12	8	do	25	do	3.5213	3.3259	2.8015	84.23

A glance at Table II shows that after 2, 4, 5, and 8 days of germination the weight of the seed was reduced, respectively, to 96.63, 92.30, 89.25, and 82.47 per cent. Equally, in the case of the uspulun-treated seed, it decreased to 96.27, 92.50, 89.93, and 84.23 per cent, after 2, 4, 5, and 8 days respectively. By means of this table the recalculation of the total nitrogen to the oven-dried seed (column 7 of Table I) is very simple. Thus, for example, No. 6 (Table I, column 6) which, after 2 days' germination was found to contain 1.77 per cent of nitrogen, calculated on the basis of the oven-dried seedlings, has 1.77×0.9663, or 1.71 per cent of nitrogen calculated on the oven-dried seed. The same considerations apply to the other tables.

AQUEOUS EXTRACTS OF THE SEEDLINGS

Although the results presented in Table I clearly establish the fact that the compounds constituting the nonprotein nitrogen are increasing with the progress of the germination, yet it seemed desirable to corroborate this finding by direct extraction with water, which, moreover, was necessary for the succeeding experiments. Accordingly, aqueous extracts were prepared as follows. Ten-gram portions of flour of the various seedlings were treated with 200 c. c. of boiling hot ammonia-free water and kept on a water bath for 30 minutes, after which the whole was centrifuged or filtered. The solid residues were treated once more in like manner. Both extracts were combined and made up to 500 c. c., of which two portions of

200 c. c. each were oxidized according to Kjeldahl's method; the remaining 100 c. c. were used for qualitative tests as well as for acidity estimation (first series). In order to obtain a more concentrated extract suitable for the trials reported in the subsequent pages, another series of extracts was prepared, in which 50-gram portions of flour were treated with hot ammonia-free water, kept on the water bath for 15 minutes, and then centrifuged. The solid residues were extracted two more times. The three extracts were made up to 500 c. c. in 25 c. c. portions, the nitrogen of which was determined according to the Kjeldahl method. The results in question are recorded in Table III.

TABLE III.—*Percentage of nitrogen extracted by water from the various seedlings*

No.	Conditions of germination				Nitrogen extracted (first series) on the basis of—			Nitrogen extracted (second series) on the basis of—		
	Duration	Substratum	Temperature	Treatment	Oven-dried seedlings	Original oven-dried seed	Total nitrogen of seedlings	Oven-dried seedlings	Original oven-dried seed	Total nitrogen of seedlings
	Days		*°C.*		*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	3	Sand	27	None	0.845	.....	49.39	.....	.....	.....
2	3	do	27	do	.834	.....	48.77	.....	.....	.....
		Average			.840	.....	49.08	.....	.....	.....
3	4	Sand	27	None	.990	.....	52.63	.....	.....	.....
4	4	do	27	do	.990	.....	52.51	.....	.....	.....
		Average			.990	.....	52.57	.....	.....	.....
5	2	Paper	30	None	.434	0.419	25.22	0.382	0.369	22.22
6	2	do	30	do	.432	.417	25.09	.370	.358	21.52
		Average			.433	.418	25.16	.376	.364	21.87
7	4	Paper	30	None	.808	.746	44.18	.722	.666	39.53
8	4	do	30	do	.808	.746	44.18	.762	.703	41.63
		Average			.808	.746	44.18	.742	.685	40.58
9	8	Paper	30	None	.998	.823	47.76	.964	.795	46.14
10	8	do	30	do	1.014	.836	48.50	.919	.758	43.96
		Average			1.006	.830	48.13	.942	.777	45.05
11	4	Paper	25	Uspulun	.695	.643	39.05	.749	.693	42.05
12	4	do	25	do	.696	.644	39.10	.....	.....	.....
		Average			.696	.644	39.08	.749	.693	42.05
13	8	Paper	25	Uspulun	.965	.813	53.01	.968	.815	53.18
14	8	do	25	do	.928	.782	51.00	.941	.793	51.71
		Average			.947	.798	52.01	.955	.804	52.45
15	11	Paper	25	Uspulun	.966	.....	50.56	.974	.....	50.98
16	11	do	25	do	1.000	.....	52.53	.955	.....	50.02
		Average			.983	.....	51.45	.965	.....	50.50

A glance at Table III shows at once that the percentage of nitrogen that could be extracted by water increases as the germination progresses. Thus, the seedlings which grew on sand at 27° for 3 days yielded an extract which contained 49.08 per cent of water-soluble nitrogen, calculated to their total nitrogen. This figure rose to 52.57

per cent in seedlings which grew for 4 days. In like manner seedlings which grew between moist paper towels for 2, 4, and 8 days yielded extracts which contained, respectively, 25.16, 44.18, and 48.13 per cent of nitrogen. Similar results were obtained with the seedlings whose seed was treated with uspulun solution. That the extracts of the second series have, as a rule, a lower nitrogen content than the corresponding extracts of the first series is due to the fact that in the latter series a considerably larger quantity of water was used for the extractions. The higher nitrogen content of the aqueous extracts in both series as compared with the nonprotein nitrogen in Table I was to be expected, because the water extracts contain, in addition to the nonprotein nitrogen compounds, also the nitrogen of soluble proteins such as albumin and proteose.

Acidity of the Aqueous Extracts

In the course of the work it was noticed that the water extracts of the different seedlings showed a more or less pronounced acid reaction. It was deemed of considerable interest to find out whether or not there is a definite relationship between the acidity on the one side and the conditions of germination on the other. With this object in view the aqueous extracts used in Table III were applied to the acidity estimations. Inasmuch as the aqueous extracts of the various seedlings were more or less colored, the color intensity increasing with the length of the germination, it was thought best uniformly to dilute all of the extracts with water so as to have identical dilutions capable of giving sharp titration end points. Accordingly, the following procedure was employed: To 20 c. c. of the water extracts in question diluted with 100 c. c. of distilled water, which was neutral to phenolphthalein, 10 drops of this indicator were added and directly titrated with N/10 sodium hydroxide. The data obtained are recorded in Table IV.

In glancing over Table IV it will be seen that the extract of the ungerminated seed (Nos. 17 and 18) showed the lowest acidity, which could be neutralized with but 0.25 c. c. tenth-normal sodium hydroxide. The acidity rose in the extracts of the seedlings that grew on sand for three and four days (Nos. 1 to 4) to 0.91 and 1.26, respectively. In like manner the extracts of seedlings that were grown on paper for 2, 4, and 8 days (Nos. 5 to 10), respectively, show a gradually increasing acidity of 0.39, 0.73, and 1.19, respectively. Similarly, the extracts of seedlings, previously treated with uspulun solution, which were grown on paper for 4, 8, and 11 days (Nos. 11 to 16) showed the acidities of 0.71, 0.93, and 1.12, respectively. Thus, in all cases the acidity may be said to have risen with the duration of the germination. The differences in acidity between the ungerminated seed on the one hand and the seedlings on the other are so great as to make unnecessary the recalculation to the weight of the original oven-dried seed.

TABLE IV.—*Acidity percentage of the various seedling extracts*

[Twenty cubic centimeters of extract used in each case]

No.	Conditions of germination				Weight of oven-dried seedlings corresponding to extract used	N/10 NaOH used for neutralization	Average
	Duration	Substratum	Temperature	Treatment			
	Days		*° C.*		*Grams*	*C. c.*	*C. c.*
1	3	Sand	27	None	0.3706	0.91	0.91
2	3	do	27	do	.3706	.91	
3	4	do	27	do	.3647	1.24	1.26
4	4	do	27	do	.3647	1.28	
5	2	Paper	30	do	.3737	.38	.39
6	2	do	30	do	.3737	.40	
7	4	do	30	do	.3726	.73	.73
8	4	do	30	do	.3726	.72	
9	8	do	30	do	.3752	1.18	1.19
10	8	do	30	do	.3752	1.20	
11	4	do	25	Uspulum	.3764	.72	.71
12	4	do	25	do	.3764	.71	
					.3764	.70	
13	8	do	25	do	.3756	.92	.93
14	8	do	25	do	.3756	.94	
15	11	do	25	do	.3773	1.07	1.12
16	11	do	25	do	.3773	1.16	
17	------	Ungerminated seed	------	------	.3658	.24	.25
18	------	do	------	------	.3658	.26	

Inasmuch as the observation was made by Schulze (*19*) and others that the organic phosphorous compounds present in seeds are gradually converted into inorganic phosphoric acid, as germination of the seeds progresses, the idea suggested itself that the acidity of the aqueous extracts of the seedlings might be due to this very reason. Although no quantitative analyses of the inorganic phosphoric acid occurring in the water extracts of the seedlings were run, repeated qualitative tests seemed to point to the fact that the rise in the acidity of the seedling extracts is to be attributed at least in part to the increase of the inorganic phosphoric acid.

DISTRIBUTION OF THE WATER-SOLUBLE NITROGEN IN THE SEEDLINGS

In order to establish the chemical nature of the organic nitrogenous compounds met with in the water extracts of the various seedlings, the following experiments were made. Ordinarily 100 or 50 gram portions of seedling flour were treated with boiling hot water and heated on the water bath for 15 minutes, after which the whole was centrifuged. The solid residues were treated twice more in like manner. The three extracts were now combined, refiltered if necessary, and made up to 1,000 c. c. or 500 c. c. In two portions of 25 c. c. each the nitrogen was estimated according to Kjeldahl's method, which gave the total water-soluble nitrogen (*a*).

From 400 c. c. of the remaining extract proteins were removed by slightly acidifying the extract with acetic acid and adding a 10 per

cent tannic acid solution as long as precipitation occurred, excess of the precipitant being avoided. After 24 hours, or sooner, the precipitate was filtered off, washed, and the filtrate and washings made up to 500 c. c. Two 25 c. c. portions of this were oxidized according to the Kjeldahl method, which gave the nitrogen of the protein-free extract (*b*).

Each of two 200 c. c. portions of this solution received enough sulphuric acid to make a 5 per cent sulphuric acid solution and boiled under a reflux condenser in a glycerine bath for two hours. On cooling, the hydrolysates were nearly neutralized with sodium hydroxide solution, made alkaline with magnesium oxide previously reduced to cream, and distilled in 1,000 c. c. Kjeldahl flasks, the distillate being received in an Erlenmeyer flask containing N/10 H_2SO_4. The titration gave the ammoniacal nitrogen corresponding to the nitrogen of acid amides present in the extracts (*c*).

The residues which remained in the 1-liter Kjeldahl flasks were thoroughly extracted with boiling hot ammonia-free water, the extracts being filtered and washed with hot water. The black substance which, together with the magnesium oxide, remained on the filter was quantitatively transferred to a 500 c. c. Kjeldahl flask and oxidized according to Kjeldahl's method. The nitrogen thus obtained represented the humin nitrogen (*d*).

All of the filtrates and washings from the black substance were together concentrated on the water bath and made up to 100 c. c. In two 10 c. c. portions of this the total nitrogen was estimated according to Kjeldahl's method, and in another two 10 c. c. portions the amino nitrogen was determined according to the method of Van Slyke (*22*, *23*, *24*, *25*), which yielded the nitrogen of amino acids present in the extracts (*e*).

To 50 c. c. of the remaining solution concentrated hydrochloric acid was added to a concentration of 20 per cent and boiled in a glycerine bath under reflux for 12 hours. The hydrolysate was next evaporated on the water bath to dryness in order to expel the hydrochloric acid, taken up with hot water and made up to 50 c. c., of which two portions of 10 c. c. each were oxidized according to the Kjeldahl method; in two other 10 c. c. portions the amino nitrogen was estimated according to Van Slyke's method. Substracting from the result thus secured the amino nitrogen present in the solution prior to the hydrolysis was obtained the nitrogen of polypeptides present in the extracts (*f*).

The residual water-soluble nitrogen, which is made up of nitrogenous compounds other than those estimated above, constitutes the difference between the protein-free water-soluble nitrogen as obtained in (*b*) and the sum of the nitrogen secured as acid-amide nitrogen in (*c*), humin nitrogen in (*d*), amino nitrogen in (*e*), and peptide nitrogen in (*f*). The results obtained by the above methods are summarized in Table V.

TABLE V.—*Partition of the water-soluble nitrogen in the various seedlings*

[Results expressed in percentage of the water-soluble nitrogen of the seedlings]

No.	Conditions of germination				Acid-amide nitrogen	Humin nitrogen	Amino nitrogen	Peptide nitrogen	Residual nitrogen
	Duration	Substratum	Temperature	Treatment					
	Days		°		*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	2	Paper	30	None	11.96	19.49	19.26	34.78	
2	2	do	30	do	10.91	19.53	22.39	33.35	
		Average			11.44	19.51	20.83	34.06	14.16
3	4	Paper	30	None	16.21	12.27	27.43	28.75	
4	4	do	30	do	14.91		28.20	24.79	
		Average			15.56	12.27	27.82	26.77	17.58
5	8	Paper	30	None	18.90	10.52			
6	8	do	30	do	18.49				
		Average			18.70	10.52			
7	4	Paper	25	Uspulun	13.90	8.57	28.06	34.52	
8	4	do	25	do	14.32		28.51		
		Average			14.11	8.57	28.29	34.52	14.51
9	8	Paper	25	Uspulun	18.32	6.54	28.89	29.52	
10	8	do	25	do	17.83	6.35	30.21	25.52	
		Average			18.08	6.45	29.55	27.52	18.40
11	11	Paper	25	Uspulun	17.87	9.22	31.70	25.98	
12	11	do	25	do	17.70	8.35	30.24	26.35	
		Average			17.79	8.78	30.97	26.17	16.29
13	15	Paper	25	Uspulun	16.71	7.06	31.86	20.98	
14	15	do	25	do	18.45	7.33	31.18	19.39	
		Average			17.58	7.20	31.52	20.19	23.50
15		Ungerminated seed			11.47	26.81	9.53	35.03	
16		do			11.78	16.58	9.51		
		Average			11.63	21.70	9.52	35.03	22.12

[Results expressed in percentage of the total nitrogen of the seedlings]

17	2	Paper	30	None	2.98	4.86	4.80	8.67	
18	2	do	30	do	2.72	4.87	5.58	8.31	
		Average			2.85	4.87	5.19	8.49	3.53
19	4	Paper	30	None	6.42	4.86	10.87	11.39	
20	4	do	30	do	5.91		11.17	9.82	
		Average			6.17	4.86	11.02	10.61	6.97
21	8	Paper	30	None	8.55	4.76			
22	8	do	30	do	8.36				
		Average			8.46	4.76			
23	4	Paper	25	Uspulun	5.39	3.32	10.87	13.38	
24	4	do	25	do	5.55		11.05		
		Average			5.47	3.32	10.96	13.38	5.62
25	8	Paper	25	Uspulun	8.61	3.08	13.59	13.88	
26	8	do	25	do	8.38	2.99	14.21	12.00	
		Average			8.50	3.04	13.90	12.94	8.65

TABLE V.—*Partition of the water-soluble nitrogen in the various seedlings*—Con.

[Results expressed in percentage of the total nitrogen of the seedlings]

No.	Conditions of germination				Acid-amide nitrogen	Humin nitrogen	Amino nitrogen	Peptide nitrogen	Residual nitrogen
	Duration	Substratum	Temperature	Treatment					
	Days		°		*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
27	11	Paper	25	Uspulun	7.67	3.96	13.61	11.15	
28	11	do	25	do	7.60	3.58	12.98	11.31	
		Average			7.64	3.77	13.30	11.23	6.99
29	15	Paper	25	Uspulun	7.38	3.12	14.06	9.26	
30	15	do	25	do	8.14	3.24	13.76	8.56	
		Average			7.76	3.18	13.91	8.91	10.37
31		Ungerminated seed			.49	1.16	.41	1.51	
32		do			.51	.71	.41		
		Average			.50	.94	.41	1.51	.95

[Results expressed in percentage of the oven-dried seedlings]

33	2	Paper	30	None	0.051	0.084	0.083	0.150	
34	2	do	30	do	.047	.084	.096	.143	
		Average			.049	.084	.089	.147	0.061
35	4	Paper	30	None	.117	.088	.198	.207	
36	4	do	30	do	.107		.203	.179	
		Average			.112	.088	.201	.193	.127
37	8	Paper	30	None	.180	.100			
38	8	do	30	do	.176				
		Average			.178	.100			
39	4	Paper	25	Uspulun	.096	.059	.194	.238	
40	4	do	25	do	.099		.197		
		Average			.098	.059	.196	.238	.100
41	8	Paper	25	Uspulun	.158	.056	.249	.254	
42	8	do	25	do	.153	.055	.260	.220	
		Average			.156	.056	.255	.237	.158
43	11	Paper	25	Uspulun	.147	.076	.260	.213	
44	11	do	25	do	.145	.068	.248	.216	
		Average			.146	.072	.254	.215	.134
45	15	Paper	25	Uspulun	.137	.058	.261	.172	
46	15	do	25	do	.151	.060	.256	.159	
		Average			.144	.059	.259	.166	.193
47		Ungerminated seed			.009	.021	.008	.028	
48		do			.009	.013	.008		
		Average			.009	.017	.008	.028	.018

DISCUSSION AND INTERPRETATION OF RESULTS

When Table V is examined certain regularities stand out quite clearly. Thus, the acid-amide nitrogen rises fairly rapidly from 0.50 per cent in the ungerminated seed (Nos. 31 and 32) to 2.85, 6.17, and 8.46 per cent (Nos. 17 to 22), respectively, after 2, 4, and 8 days of germination, calculated on the basis of the total nitrogen. This is also true of the uspulun-treated seed, which after 4 days of

germination showed 5.47 per cent (Nos. 23 and 24), and after 8 days it rose to 8.50 per cent (Nos. 25 and 26). In the period from the eighth to the fifteenth day the acid-amide nitrogen remained almost constant (showing a slight diminution). The same regularities hold good when the latter is calculated to the water-soluble nitrogen or to the oven-dried seedlings.

The reverse, however, holds good for the humin nitrogen. Thus, while the ungerminated seed (Nos. 15 and 16) showed 21.70 per cent, it gradually decreased to 19.51, 12.27, and 10.52 per cent (Nos. 1 to 6) after 2, 4, and 8 days, respectively. The same is true of the uspulun-treated seed, which after 4 days of germination had 8.57 per cent (No. 7), but after 8 days had but 6.45 per cent (Nos. 9 and 10), calculated on the water-soluble nitrogen. In the period from the eighth to the fifteenth day the humin nitrogen showed a slight increase.

With regard to the amino nitrogen, it will be seen that from 9.52 per cent in the ungerminated seed (Nos. 15 and 16) it rose rather rapidly to 20.83 and 27.82 per cent after 2 and 4 days, respectively. Equally, the uspulun-treated seed showed an increase to 28.29, 29.55, 30.97, and 31.52 per cent after 4, 8, 11, and 15 days (Nos. 7 to 14), respectively, calculated on the basis of the water-soluble nitrogen. About the same relationship holds good when the amino nitrogen is calculated on either the total nitrogen or the oven-dried seedlings.

The figures for the peptide nitrogen show a reverse relationship. Thus, while the ungerminated seed (Nos. 15 and 16) had 35.03 per cent, it diminished to 34.06 and 26.77 per cent after 2 and 4 days, respectively, and in the case of the uspulun-treated seed it changed to 34.52, 27.52, 26.17, and 20.19 after 4, 8, 11, and 15 days, respectively, when calculated to the water-soluble nitrogen. The fact that the amino nitrogen rose at the same time that the peptide nitrogen diminished seems to indicate that the former increased at the expense of the latter.

The residual nitrogen, representing the difference between the total soluble nitrogen and the sum of the various nitrogenous compounds estimated, is rather fluctuating, as would be expected.

In Nos. 33 to 48 the results expressed in percentage of the oven-dried seedlings were given for the sake of completeness. These have not been recalculated to the original oven-dried seed.

The results in Table V are based upon the aqueous extracts (of the seedlings) which were successively treated with acetic and tannic acids. Although this treatment removes the proteins, it may not remove proteoses and peptones quantitatively (*1, p. 609*). If such be the case, the increase in amino nitrogen, on hydrolysis, as reported previously, could be due not only to the presence of polypeptides but also to that of proteoses and peptones. Hence, it seemed necessary, quantitatively, to remove any proteoses and peptones present prior to the hydrolysis. This was accomplished with the aid of phosphotungstic acid by the following method: On distilling off the ammonia, corresponding to the nitrogen of acid amides, the filtrate and washings from the magnesium oxide residue were concentrated on the water bath and made up to 100 c. c. On cooling, the solution was treated with 5 gms. of sulphuric acid and

30 c. c. of a solution containing 20 gms. of phosphotungstic acid and 5 gm. of sulphuric acid per 100 c. c. After 24 hours, the precipitate was filtered off and washed with 200 c. c. of a solution containing 5 gms. of sulphuric acid and 2.5 gms. of phosphotungstic acid per 100 c. c., the washing being accomplished by rinsing the precipitate from filter into a beaker and returning to the filter three times. The washed precipitate was then oxidized according to the Kjeldahl method, yielding the nitrogen of any proteoses and peptones present, as well as of diamino acids.

The filtrate from the phosphotungstic acid precipitate was treated with calcium hydroxide to slight acidity, then with barium hydroxide to distinct alkalinity, saturated with carbon dioxide, heated, filtered on Büchner, and thoroughly washed with boiling hot ammonia-free water. The residual cake was extracted at least once more with hot water. The filtrates and washings from sulphate, phosphotungstate, and carbonate of calcium and barium were ordinarily saturated once more with carbon dioxide, and when clear concentrated in a vacuum, filtered, and made up to 100 c. c., of which 50 c. c. were used directly for the estimation of the amino nitrogen according to Van Slyke's method, and in the other 50 c. c. the amino nitrogen was estimated, on hydrolysis, as outlined above. By this method in which any proteoses and peptones present are removed, quantitatively, it was found that, on the average, after two days the seedling extract contained 22.08 per cent of amino nitrogen and 33.83 per cent of peptide nitrogen; after four days it contained 23.08 per cent of amino nitrogen and 30.60 per cent of peptide nitrogen, calculated on the basis of the water-soluble nitrogen. These figures reasonably approximate those obtained by the tannic-acid method alone, as a glance at columns 8 and 9 of Table V shows.

PROTEOLYTIC ENZYMES

The appearance of polypeptides, amino acids, and acid amides—well known disintegration products of proteins—in the aqueous extracts of the corn seedlings is to be attributed to the action of proteolytic enzymes. In view of the doubt expressed by some writers (*2*) as to whether these enzymes appear for the first time during the process of germination or are preexistent in the resting seed, it should be emphasized that the proteases are unquestionably preexistent in the ungerminated corn seed, since the latter was shown by the writer (*11*) to contain polypeptides and amino acids. This is further confirmed by the observation that the resting seed respires like the growing plant, though in a very much lesser degree (*4*), and it is for this reason that the decrease in weight shown by cereal grains during their storage is to be ascribed not only to loss of water but also to loss of carbon dioxide. The acid reaction which has been shown in this paper gradually to increase as germination of the corn seed progresses is a powerful aid to the proteases in their degradation of the proteins, since the action of proteolytic enzymes is known to be very much more intensive in an acid medium than in one that is neutral or alkaline (*26, p. 223*).

SUMMARY

By the process of germination, in the absence of light, the proteins present in the corn seed are rapidly undergoing disintegration whereby, within 8 days, up to 48 per cent of them are converted into water-soluble, diffusible nitrogen compounds.

The disintegration takes place through the activity of proteolytic enzymes which are to be considered as preexistent in the resting corn seed, since the latter was shown by the writer to contain polypeptides and amino acids, degradation products of protein.

From the beginning of corn germination up to the eighth day there is a steady increase in acid-amide nitrogen and a decrease in humin nitrogen. This is interpreted to mean that acid amides increase at the expense of certain amino acids which are known to contribute to the formation of humin nitrogen, such as tryptophane and tyrosine (*5*).

During the first eight days of corn germination there is also a steady rise in amino nitrogen and a diminution in peptide nitrogen. This is taken to mean that amino acids increase at the expense of polypeptides which, along with proteoses, are among the first degradation products of proteins.

The nitrogen distribution of the aqueous extracts of the etiolated corn seedlings, calculated to the water-soluble nitrogen, is as follows. After 2 days: 11.44 per cent of amide nitrogen, 19.51 per cent of humin nitrogen, 20.83 per cent of amino nitrogen, and 34.06 per cent of peptide nitrogen. After 4 days: 15.56 per cent of amide nitrogen. 12.27 per cent of humin nitrogen, 27.82 per cent of amino nitrogen, and 26.77 per cent of peptide nitrogen. After 8 days (in uspulun-treated seedlings): 18.08 per cent of amide nitrogen, 6.45 per cent of humin nitrogen, 29.55 percent of amino nitrogen, and 27.52 per cent of peptide nitrogen.

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MINERAL COMPOSITION OF SUNFLOWERS GROWN FOR SILAGE[1]

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INTRODUCTION

Sunflowers already have gained an important place among silage crops in the Pacific Northwest, chiefly because of their resistance to drought and frost and the high tonnage of forage produced per acre. Many high yields have been reported. In seasons of abundant rainfall 20 tons or more per acre have been obtained, while in seasons of deficient moisture approximately 10 tons are obtained. The fact that sunflowers usually result in high yields of forage per acre has given rise to the question by many agriculturists as to the effect of sunflowers on the following crop. Repeated observations have indicated that crops following sunflowers have been markedly decreased. To answer the common query of the farmers, "Do sunflowers deplete the soil nutrients?" a study was undertaken by the Idaho Agricultural Experiment Station to determine the amount of plant foods removed from the soil when sunflowers were grown under different systems of plantings. The Maryland station [2] has recently reported that sunflowers "draw about as heavily as other crops upon the nitrogen of the soil, less heavily than grain upon the phosphorus, and more heavily than other crops upon the potash. Owing to its heavy growth it exhausts unduly the plant food of the soil, and should therefore be grown in rotation with other crops."

Samples of sunflowers grown at the Idaho station in 1920 under different systems of plantings, and harvested at different stages of maturity, have been analyzed for their food constituents and the results reported in a previous publication.[3] Quantities of each sample remained, and these offered an excellent opportunity to study the mineral content of sunflowers when harvested at different stages in their growth and under different systems of planting. For the complete plan of the experiment the reader is referred to the former publication.[4]

The sunflowers were grown on Palouse silt loam soil, which has the following general composition, as determined by Peterson:[5]

TABLE I.—*Composition of Palouse silt loam soil* [a]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Mgo	Na_2O	K_2O	MAO	CO_2	P_2O_5	SO_3	N	Organic CO_2
Surface soil	67.66	14.90	4.44	2.89	1.31	2.72	1.96	0.0	0.04	0.160	Trace.	0.16	5.80
Subsoil	68.10	14.95	4.48	2.57	1.60	2.76	2.05	0.0	.03	.154	Trace.	.10	3.45

[a] Figures indicate percentages.

[1] Received for publication Feb. 5, 1925; issued December 1925. Published by the permission of the director as Paper No. 35 of the Idaho Agricultural Experiment Station, 1925.

[2] ALLEN, E. W., BEAL, W. H., and FLINT, E. R. WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1922, p. 28, 1924. (U. S. Dept. Agr., Office Exp. Sta.).

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[5] PETERSON, P. P. SOILS OF LATAH COUNTY, IDAHO. Idaho Agr. Exp. Sta. Bul. 107, 21 p., illus. 1918.

METHODS

The sunflowers were planted in rows 42 inches apart, the systems of planting differing in the distances apart (8 inches and 24 inches) in the row, and the number of plants (1, 2, 3, and 4) in the hill. The plants were collected and analyzed at five stages of growth.

STAGES SELECTED

The stages of maturity selected were as follows: First, when the bud was appearing on the top of the plant; second, when the first flower was about 3 inches in diameter but no seed had developed; third, just before the seeds of the first flower were in the dough stage; fourth, when the seeds of the first flower were well in the dough stage and the rays were just beginning to fall; fifth, when the seeds of the first flower were quite hard and its rays had fallen.

METHOD OF SAMPLING

Ten representative plants were collected, weighed, and measured, and then composited after cutting in a small silage cutter and mixing thoroughly. After complete desiccation, 250 grams were weighed out and carefully ashed. To prevent volatilization of the chlorides during ashing, the usual precautions were taken, that of leaching the residue after charring, then evaporating the leachings to a small volume, and incorporating this with the residue after burning the residue thoroughly in an electric muffle.

This residue is called the crude ash. Pure ash was obtained by dissolving the crude ash with hot dilute hydrochloric acid and filtering. The residue was again treated in the same manner and the filtrates combined and made up to a definite volume. Analyses of the pure ash were made in accordance with the methods outlined by the Association of Official Agricultural Chemists.[6] In addition, total sulphur was determined on the finely ground unburned anhydrous material using the Parr Bomb method in contrast to the inorganic sulphur in the pure ash which was determined by the usual A. O. A. C. methods.

RESULTS

Table II contains data on the size and weight of stalks, the yield per acre, and the percentage of crude and pure ash for all the systems of plantings.

Table III contains data showing the mineral content of the ash of sunflowers expressed as percentage of the pure ash and also as percentage of anhydrous material for all systems of plantings and for all stages harvested.

[6] ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. AS COMPILED BY THE COMMITTEE ON REVISION OF METHODS. REVISED TO NOV. 1, 1919. 417 p., illus. Washington, D. C. 1920.

TABLE II.—*Sunflower data*

No.	Stage	Number in hill	Distance apart in rows	Number of stalks taken	Height	Average weight one stalk	Moisture	Yield per acre	Anhydrous yield per acre	Crude ash	Insoluble residue	Pure ash
			Inches		*Ft. in.*	*Pounds*	*Per cent*	*Tons*	*Tons*	*Per cent*	*Per cent*	*Per cent*
11005	1	1	8	10	6 6	1.38	81.40			15.96	1.55	14.41
	2	1	8	10	6 1	1.53	83.44			14.12	1.86	12.25
	3	1	8	10	6 1	1.89	82.65			15.76	2.18	13.58
	4	1	8	10	6 1	2.05	81.40			14.00	1.56	12.44
	5	1	8	10	6 0	1.95	77.40	10.40	2.35	14.12	1.45	12.67
11008	1	1	24	10	6 0	2.40	82.40			17.88	2.47	15.41
	2	1	24	10	6 0	2.80	81.93			17.31	3.05	14.25
	3	1	24	10	6 4	3.53	82.20			14.28	1.93	12.35
	4	1	24	10	6 6	4.34	82.53			13.28	1.61	11.67
	5	1	24	10	6 0	4.86	79.40	7.20	1.48	12.76	1.38	11.38
11010	1	1	42	5	5 10	5.22	84.14			19.00	2.42	16.57
	2	1	42	5	5 5	5.16	85.53			16.48	1.91	14.57
	3	1	42	5	5 11	6.12	83.57			14.56	2.14	12.42
	4	1	42	5	5 11	8.02	83.80			13.52	1.70	11.82
	5	1	42	5	5 6	8.20	79.40	9.70	2.00	12.00	1.97	10.03
11011	1	2	42	10	5 11	2.53	83.40			17.60	2.89	14.71
	2	2	42	10	6 2	2.73	83.67			15.76	2.30	13.46
	3	2	42	10	6 2	3.41	82.23			13.36	1.78	11.58
	4	2	42	10	5 10	4.35	82.07			13.36	1.77	11.59
	5	2	42	10	6 0	5.04	79.20	10.30	2.14	10.76	1.20	9.55
11002	1	3	42	10	6 4	1.93	82.90			17.84	2.04	15.80
	2	3	42	10	6 2	2.05	81.87			14.32	1.58	12.73
	3	3	42	10	6 5	2.85	82.43			15.64	2.01	13.62
	4	3	42	10	6 4	4.06	83.00			14.67	1.70	12.97
	5	3	42	10	6 0	4.38	78.14	10.00	2.19	12.40	1.27	11.13
11013	1	4	42	10	6 0	2.10	84.54			11.96	1.72	10.23
	2	4	42	10	6 1	2.02	82.40			14.56	1.94	12.61
	3	4	42	10	6 7	2.71	84.25			15.32	1.88	13.44
	4	4	42	10	5 10	2.73	79.70			13.36	1.49	11.86
	5	4	42	10	6 3	2.70	78.60	9.20	1.97	11.92	1.29	10.63

Table IV contains the data showing the amount of plant food in pounds removed per acre when sunflowers were cut for silage. The results are given for only the fifth stage, and are representative of the amount of plant food removed per acre by sunflowers when harvested for silage under field conditions. The results are stated as pounds of elements removed per acre by the different systems of planting, basing the calculations on the actual yields obtained. From the table it is seen that the yields are quite similar in all the systems of plantings, except Plot No. 11008, where the plants were spaced 24 inches apart in the row. This yield is low and should be attributed to differences in soil and moisture conditions rather than the spacing.

TABLE III.—*Ash of Sunflower plants*

No.	Stage	Number in hill	Distance apart in rows	Mineral content expressed in per cent of pure ash							Mineral content expressed in per cent of anhydrous material							
				Fe_2O_3 and Al_2O_3	MnO_4	CaO	P_2O_5	K_2O	MgO	Inorganic sulphur	P_2O_5	Fe_2O_3 and Al_2O_3	MnO_4	CaO	K_2O	MgO	Inorganic sulphur	Total sulphur
			Ins.															
11005	1	1	8	0.944	0.750	14.29	4.021	40.21	2.220	0.534	0.580	0.136	0.108	2.060	5.800	0.320	0.077	0.294
	2	1	8	1.200	1.436	16.36	4.279	38.61	4.556	.699	.524	.147	.176	2.006	4.731	.558	.086	.280
	3	1	8	1.546	.942	18.67	3.800	36.20	4.562	.696	.516	.210	.128	2.536	4.918	.620	.094	.270
	4	1	8	1.076	.981	16.30	3.879	33.36	4.483	.531	.495	.134	.122	2.028	4.154	.558	.066	.204
	5	1	8	1.065	1.121	15.90	3.621	27.48	5.160	.507	.459	.135	.142	2.016	3.480	.654	.064	.278
11008	1	1	24	1.220	.882	16.18	3.942	34.82	5.010	.582	.608	.188	.136	2.492	5.370	.772	.090	.408
	2	1	24	1.369	.828	19.13	5.056	33.91	5.040	.860	.720	.195	.118	2.724	4.835	.718	.122	.324
	3	1	24	.915	1.409	19.82	4.592	36.29	5.130	.582	.567	.113	.174	2.448	4.480	.572	.072	.308
	4	1	24	.848	1.457	19.15	4.816	34.50	3.990	.631	.562	.099	.170	2.234	4.025	.466	.074	.280
	5	1	24	.852	1.387	19.66	5.760	33.11	4.834	.862	.656	.097	.158	2.238	3.770	.550	.098	.326
11010	1	1	42	1.026	.482	26.83	4.228	35.55	4.740	.685	.701	.170	.080	4.448	5.896	.786	.113	.250
	2	1	42	.934	.700	26.20	4.680	38.58	3.308	.906	.682	.136	.102	3.818	5.620	.482	.132	.286
	3	1	42	1.192	.966	24.90	5.475	36.01	3.333	.862	.680	.148	.120	3.092	4.476	.414	.107	.218
	4	1	42	1.422	.677	22.50	5.418	40.75	2.708	1.002	.640	.168	.080	2.660	4.818	.320	.118	.234
	5	1	42	1.625	.877	26.83	6.327	34.60	8.510	.804	.635	.163	.088	2.692	3.472	.854	.081	.182
11011	1	2	42	1.516	1.006	22.46	4.610	38.30	5.140	.823	.678	.223	.148	3.304	5.636	.756	.121	.220
	2	2	42	1.284	.549	19.20	4.960	39.70	4.040	.921	.668	.173	.074	2.586	5.348	.544	.124	.456
	3	2	42	1.235	1.364	18.28	5.008	38.80	5.940	.870	.580	.143	.158	2.118	4.496	.688	.101	.260
	4	2	42	1.036	.811	20.33	5.108	38.80	4.622	.835	.592	.120	.094	2.358	4.498	.536	.097	.224
	5	2	42	1.256	1.006	20.46	5.658	39.11	7.250	.796	.540	.120	.096	1.954	3.736	.692	.076	.218
11002	1	3	42	1.158	.722	25.48	4.140	34.94	5.152	.919	.654	.183	.114	4.022	5.520	.814	.145	.330
	2	3	42	.935	.833	20.58	4.467	38.80	4.505	.845	.569	.119	.106	2.620	4.940	.574	.107	.332
	3	3	42	1.079	.983	18.10	4.850	41.28	4.840	.723	.661	.147	.134	2.466	5.622	.660	.098	.306
	4	3	42	1.041	.740	15.81	5.260	34.48	4.500	.740	.682	.135	.096	2.050	4.472	.584	.096	.280
	5	3	42	1.005	.826	19.16	5.480	33.35	4.165	.741	.610	.112	.092	2.134	3.715	.464	.082	.306
11013	1	4	42	1.515	1.212	20.79	6.150	48.05	7.175	1.171	.629	.155	.124	2.126	4.918	.734	.120	.174
	2	4	42	1.332	.539	16.75	5.900	38.65	6.120	.996	.744	.168	.068	2.112	4.876	.772	.126	.262
	3	4	42	1.272	.982	18.40	5.120	40.65	5.520	.926	.688	.171	.132	2.472	5.464	.742	.124	.228
	4	4	42	1.483	1.011	18.46	6.060	39.38	2.629	.978	.719	.176	.120	2.190	4.674	.312	.116	.220
	5	4	42	1.138	.903	20.00	5.905	40.61	3.970	.730	.628	.121	.096	2.128	4.320	.422	.078	.170

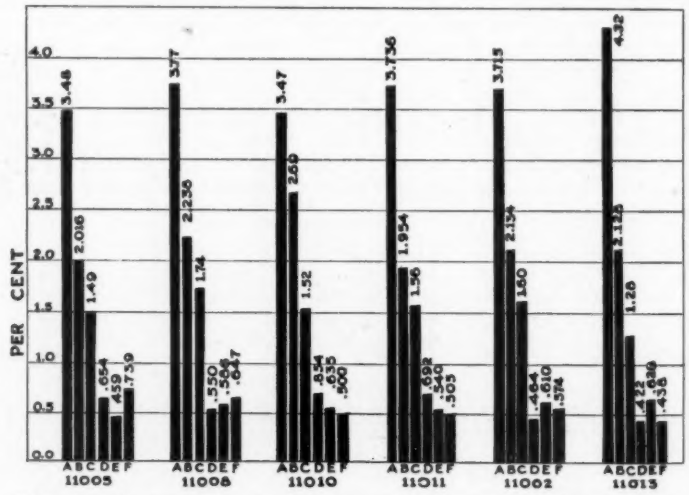


FIG. 1.—Percentage composition of sunflowers, expressed on the anhydrous basis for the different systems of planting. (Fifth stage only.) A=K_2O; B=CaO; C=N; D=MgO; E=P_2O_5; F=other elements

The variations observed in yields are due for the most part to the uneven moisture and fertility conditions, because of the uneven contour of the land. Figure 1 represents graphically the percentage of mineral elements in the ash of sunflowers from all systems of planting, based on the anhydrous material. Since the majority of the systems of plantings yielded sunflowers to the amount of approximately 10 tons, a graphic representation of the pounds of mineral elements removed from 1 acre by sunflowers when cut for silage is given in Figure 2.

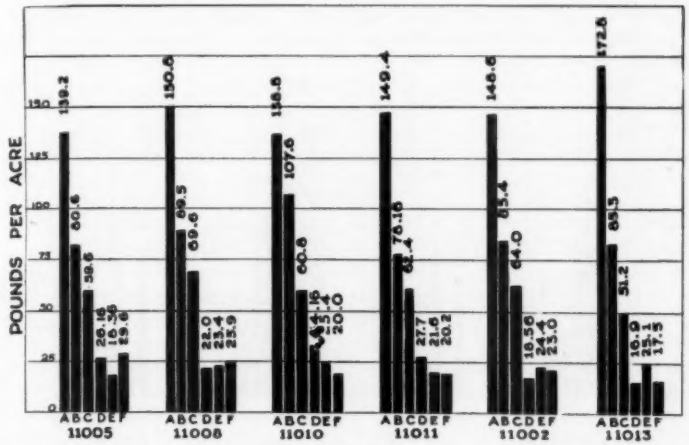


FIG. 2.—Pounds of elements removed per acre by a 10-ton per acre crop of sunflowers. A=K_2O; B=CaO; C=N; D=MgO; E=P_2O_5; F=other elements

In calculating the pounds removed per acre, the moisture percentage taken for all stages was arbitrarily placed at 80 per cent, which is relatively near the average moisture for sunflowers when cut at this stage for silage.

TABLE IV.—*Analysis of ash of sunflowers—actual pounds of elements removed per acre*

[Fifth stage only, i. e., when seeds of first flower were quite hard and its rays had fallen]

No.	Number in hill	Distance apart in rows	Crude ash	Insoluble residue	Pure ash	P_2O_5	Fe_2O_3 and Al_2O_3	Mn_3O_4	CaO	K_2O	MgO	Inorganic sulphur	Total sulphur	Weight anhydrous sunflowers per acre
		Inches												*Pounds*
11005	1	8	663.8	68.3	595.5	21.58	6.35	6.68	94.77	163.6	30.74	3.02	13.07	4,701
11008	1	24	378.5	40.96	337.5	19.46	2.88	4.69	66.38	111.8	16.31	2.91	9.67	2,966
11010	1	42	479.5	78.76	400.8	25.37	6.51	3.52	107.57	138.7	34.13	3.22	7.27	3,996
11011	2	42	461.1	51.63	409.5	23.14	5.14	4.11	83.73	160.1	29.65	3.26	9.34	4,285
11002	3	42	542.1	55.70	486.4	26.67	4.90	4.02	93.30	162.4	20.29	3.61	13.38	4,372
11013	4	42	469.4	50.88	418.5	24.73	4.76	3.78	83.80	170.1	16.62	3.06	6.69	3,938
Average			499.1	57.71	441.4	23.50	5.09	4.47	88.28	151.1	24.62	3.18	9.90	4,043

Figure 3 contains a graphic comparison of the average analysis of 55 sunflower plants analyzed by the writers, and of 5 corn plants calculated from data published by Latshaw.[7] In addition a comparison of the amount of elements removed from an acre of sunflowers and corn is made, assuming the yield of each crop to be 10 tons and the moisture percentage of sunflowers 80 per cent, while corn is calculated at 70 per cent. Latshaw's analyses are used for the basis of the corn calculations.

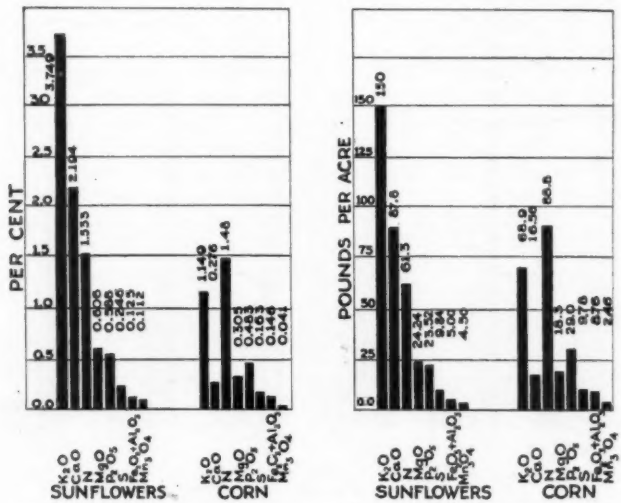


FIG. 3.—Comparison of the percentage composition and pounds of elements removed per acre by 10-ton per acre crops of sunflowers and corn

A comparison of the percentage composition of mineral elements in sunflowers when grown under the different systems in this investigation shows that regardless of the spacings or type of planting, the percentage composition is approximately the same. The greatest variation is found in plot 11013, which contained four plants per hill. These plants drew the heaviest upon the potash of the soil and gave the lowest percentage of nitrogen. An examination of this particular group of plants through the five stages of growth shows a limited growth in the later stages. This may be due to the inability of the roots to feed over as large an area in the hill system with four plants as when spaced at stated distances in the row.

COMPARISON OF ELEMENTS IN SUNFLOWERS AND CORN

Sunflowers draw very heavily on potassium and calcium and to some extent on magnesium. They draw much more heavily on these bases than does corn. As to the other elements, sunflowers and corn take about the same amounts out of the soil.

[7] LATSHAW, W. L., and MILLER, E. C. ELEMENTAL COMPOSITION OF THE CORN PLANT. Jour. Agr. Research 27: 845-860, illus. 1924.

Figure 3 shows the difference in the mineral composition of sunflowers and corn when expressed as percentage of the dry material and when expressed as pounds removed per acre, assuming an arbitrary yield of 10 tons for each crop. The moisture content of sunflowers was placed at 80 per cent and corn at 70 per cent, which is near the average figure for each crop.

Comparing the percentage composition it is seen that sunflowers contain more than three times as much potassium oxide, eight times as much calcium oxide, and twice as much magnesium oxide, as does corn. The percentage composition in respect to phosphorus pentoxide, sulphur, and other elements is about the same for both crops, there being slightly greater percentages in sunflowers than in corn.

In spite of the fact that a 10-ton yield of sunflowers, as cut for silage, yields only 4,000 pounds of anhydrous material, while 10 tons of corn yields 6,000 pounds, it is found that the amount of bases removed by sunflowers is still much greater than is removed by corn as cut for silage. The two elements showing the greatest differences are potassium and calcium, 150 pounds of potassium oxide and 87.8 pounds of calcium oxide being removed by sunflowers as against 68.9 pounds of potassium oxide and 16.6 pounds calcium oxide by corn. Magnesium oxide is about 1⅓ times greater, there being 24.24 pounds removed by the sunflowers and 18.3 pounds by the corn. Sulphur is removed in approximately the same amounts by both crops, sunflowers removing 9.84 pounds and corn 9.78 pounds per acre. More phosphorus pentoxide is removed by corn than by sunflowers, the amounts being 29 pounds and 23.5 pounds, respectively.

While the percentage of nitrogen is approximately the same in sunflowers and corn, the amount removed by the 10-ton crop of corn is greater than that removed by a corresponding crop of sunflowers, due to the greater amount of anhydrous material. A 10-ton yield of corn contains 88.8 pounds nitrogen as against 61.3 pounds for the similar yield of sunflowers.

The reason that low yields of crops somtimes follow sunflowers may be due to the heavy draft which a sunflower crop makes on the soluble minerals of the soil, a heavy crop of sunflowers requiring especially a large supply of potassium and calcium. It is readily seen, therefore, that sunflowers, when grown, should be included in a rotation.

SUMMARY

The composition of the ash of sunflowers has been determined for different systems of plantings and for different stages of growth.

A comparison of the minerals removed by 10-ton crops of sunflowers and corn is given.

Sunflowers draw more heavily than corn upon certain soil elements, especially potassium and calcium.

INFLUENCE OF FIELD-PEA RATIONS ON THE QUALITY OF PORK[1]

By J. E. NORDBY, *Assistant Animal Husbandman, Department of Animal Husbandry*, and ROBT. S. SNYDER, *Associate Chemist, Department of Agricultural Chemistry, University of Idaho*

INTRODUCTION

More and more during recent years, field peas have been replacing summer fallow in Idaho. It seems quite probable that they will be grown to increasing extent as their value in rotation systems becomes more generally appreciated.

Two types of feeding field peas have come into general use among farmers in the State: First, "hogging-off"; and, second, feeding in the dry lot, especially cull peas that are not suitable for seed. In work done at the Idaho station [2] during the last eight years, an average of 406 pounds of pork have been produced per acre by the "hogging-off" method, while in the dry lot less than 400 pounds of peas have been required per 100 pounds of gain. In some cases unthreshed pea vines have been harvested and used for either wintering or finishing hogs.

As a result of their general use, many questions have come to this station relative to the value of peas with respect to their specific influence on the quality of pork produced when fed alone, or in combination with standard concentrates. A few complaints have been made that hogs finished on peas were discriminated against at market because "they lacked the firmness which characterizes hogs fed on corn or barley and that they killed out soft carcasses."

Reference is made to this problem by Shaw [3] who concludes that "peas are superior to corn as a food for pigs at any time prior to the fattening season; hence they may be fed to swine more freely, but in no instance should they form the sole ration before the finishing period begins. 'During the fattening period they are unexcelled when fed as the sole grain food. They promote growth, while they fatten in excellent form, and they furnish a sweet, firm, and excellent quality of pork.'" Day [4] refers to pea meal as "a valuable food," but says it "should never be fed alone. * * * Peas are noted for the excellent quality of bacon which they produce." Toole and Knox [5] include peas as a desirable forage for developing bacon hogs, and Grisdale [6] says "peas are 'undoubtedly of very high value as a feed for the production of good, firm bacon, and for young pigs and breeding stock of all classes at practically all times. They should,

[1] Received for publication Feb. 5, 1925; issued December, 1925. Published with approval of the director as paper No. 31 of the Idaho Agricultural Experiment Station. The writers are indebted to C. W. Hickman, head of the Department of Animal Husbandry, and Ray E. Neidig, head of the Department of Agricultural Chemistry, University of Idaho, for valuable suggestions in the planning and carrying out of the work.

[2] GONGWER, R. E. FIELD PEAS FOR PORK PRODUCTION. Idaho Agr. Exp. Sta. Bul. 125, 8 p., 1921. Unpublished data.

[3] COBURN, F. D. SWINE IN AMERICA. p. 356. New York and London. 1909.

[4] DAY, G. E. BACON PRODUCTION. Ontario Agr. Col. and Exp. Farm Bul. 129, 23 p., illus. 1903.

[5] TOOLE W., and KNOX, R. G. BREEDING, GROWING AND FINISHING "THE BACON HOG." Ontario Agr. Col. and Exp. Farm Bul. 299, 10 p., illus. 1923.

[6] COBURN, F. D. Op. cit. p. 357.

however, never be fed alone, and should always be ground. Pigs fed on pea meal alone do not thrive, do not get fat, and produce a very inferior quality of meat, dry and hard.' " Peas, largely in the form of meal, have a rather important part in hog feeding in Europe where bacon production is a specialty.

PURPOSE

The purpose of this investigation is to study the quality of pork produced from field peas exclusively and compare it with pork obtained from pea-barley, barley-tankage, and corn-tankage rations, from the standpoint of shrinkage in the curing processes, melting ponts, and iodine values.

PLAN

Two methods of feeding were adopted. In part 1 the hogs were confined to the dry lot. In part 2 a preliminary forage period preceded the dry-lot feeding.

PART 1

Thirty-two thrifty, uniform, Duroc-Jersey shotes, averaging 120 pounds, were divided into 4 lots, and fed for 76 days (February 23 to May 9, 1923), on the following rations:

Lot I, cracked peas alone.
Lot II, cracked peas 3, barley 7.
Lot III, rolled barley 15, tankage 1.
Lot IV, cracked corn 9, tankage 1.

In addition to these rations, all lots received, with the evening feed, 2 pounds of the following mineral mixture: 100 pounds bone meal, 100 pounds charcoal, 50 pounds common salt, 50 pounds sulphur, 25 pounds copperas.

PART 2

Forty-six well-developed, uniform, Poland-China and Duroc-Jersey shotes, averaging 98.5 pounds, were divided into 4 lots. A forage period of 30 days was introduced prior to the dry-lot feeding, according to the following plan:

Lot I, hogging-off, 0.85 acre peas.
Lot II, hogging-off, 0.95 acre peas, and in addition a 1 per cent ration of rolled barley.[7]
Lot III, alfalfa forage and a full ration of rolled barley 15, tankage 1.
Lot IV, alfalfa forage, and a full ration of cracked corn 12, and tankage 1.

Feeding was then continued in the dry lot, as follows:

Lot I, cracked peas alone.
Lot II, cracked peas 7, rolled barley 2.
Lot III, rolled barley 14, tankage 1.
Lot IV, cracked corn 10, tankage 1.

[7] Eleven hogs were used in lots I, III, and IV. Two additional hogs were used in lot II in order to hog off the peas at the same rate as in lot I.

RESULTS

All lots in both parts of this series were provided with comfortable accommodations. Weight records were made of each pig every 14 days. The initial and final weights of each test represent the average weight of three consecutive days, the second of which marks the beginning and close of the test.

The hogs were marketed at a packing plant in Moscow, Idaho. Careful records were kept on each lot as to dressing percentages, shrinkage in the cooler, and gains or losses in the curing and smoking processes. Physical observations were made as to the quality of pork.

For the determination of the melting points and iodine values, samples of fat were taken from the middle of the back and from the leaf after the carcasses were chilled. Each sample was rendered separately and poured into small glass bottles. All chemical analyses were made according to the Official Methods of the Association of Official Agricultural Chemists.[8]

The composition of all feeds used was as follows:

TABLE I.—*Composition of feeds*

Feed	Moisture	Ash	Crude protein	Crude fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Blue Prussian peas	9.87	4.17	22.33	4.31	57.38	1.94
White winter barley	9.65	2.72	12.26	6.10	67.31	1.96
Yellow Dent corn	10.97	1.55	10.07	2.16	73.17	2.08
60 per cent digester tankage	7.02	17.18	57.79	2.62	2.70	12.69

Tables II, III, and IV are introduced to show the average daily gain, the amount of feed per 100 pounds gain, and the dressing percentages of each lot under the two types of feeding.

An economy of gain is registered in the peas-following-forage lot in Table IV as compared to the pea lot in Table III. A forage period has the same effect in the case of all other lots.

The dressing percentages of the pea-fed lots were somewhat lower than those in the other lots. It appeared to be the tendency of the pea-fed hogs to grow rather than to fatten, which will account for the lower dressing percentages. It will be noted that the feed requirement for 100 pounds of gain is in favor of the pea-fed lots, and that an unusually low amount was required in Lot I, Table III. The pea-fed hogs did not display the vigorous appetite at all times that was evident in the lots receiving mixed rations. In all cases, the feed requirement per 100 pounds of gain was quite satisfactory.

[8] ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. AS COMPILED BY THE COMMITTEE ON REVISION OF METHODS. REVISED TO NOV. 1, 1919. 417 p., illus. Washington, D. C. 1920.

TABLE II.—*Comparison of peas, barley, corn, and tankage in the following combinations for finishing hogs (part 1)*

Ration	Lot 1: Peas	Lot 2: Peas 3, barley 7	Lot 3: Tankage 1, barley 15	Lot 4: Tankage 1, corn 9
Average daily gain (pounds)	1.36	1.41	1.31	1.41
Pounds of feed per 100 pounds gain	378.40	410.90	438.34	409.52
Dressing percentages	77.03	80.46	78.57	81.13

TABLE III.—*Hogging-off peas as the only ration: Hogging-off peas with 1 per cent barley, and alfalfa forage with full grain ration (part 2)*

Ration	Lot 1: 0.85 acre peas	Lot 2: 0.95 acre peas, barley 1 per cent ration	Lot 3: Alfalfa forage, barley 15, tankage 1	Lot 4: Alfalfa forage, corn 12, tankage 1
		Per cent		
Average daily gain (pounds)	0.96	1.07	1.17	1.30
Pounds of supplementary feed per 100 pounds gain		101.20	400.30	360.80

TABLE IV.—*Forage lots continued on the following rations (part 2)*

Ration	Peas	Peas 7, barley 2	Barley 14, tankage 1	Corn 10, tankage 1
Average daily gain (pounds)	1.49	1.64	2.02	2.01
Pounds of feed per 100 pounds gain	362.20	393.40	411.30	414.70
Dressing percentages	74.00	74.20	79.10	78.50

COOLING AND CURING RESULTS

The carcasses were cooled 48 hours in a direct-expansion type of cooler at a temperature of 35° F. It was deemed sufficient to keep records through the curing and smoking processes on the sides (bellies) only. The bellies in part 1 were placed in the sweet-pickle cure (salometer reading 60) for 33 days, then removed and drained for 10 hours before weighing into the smoke. After smoking 14 hours at a temperature of from 90° to 110° F. they were cooled for 8 hours and weighed.

In part 2, the bellies were cured by the dry-salt process for 25 days. After removing from the salt they were soaked 4 hours and allowed to drain 10 hours before weighing into the smoke. From this point the procedure was the same as in part 1.

A summary of results, as shown in Table V indicates very small difference between the various lots in either part 1 or part 2. It would seem rather difficult to point to any significant variation in these tables which might tend to indicate any appreciable difference in the lots involved.

TABLE V.—*Summary of results in the cooling, curing, and smoking processe*

Lot No.	Part 1.—Sweet-pickle cure					Part 2.—Dry-salt cure				
	Fresh chilled weight	Cooled smoked meat	Loss			Fresh chilled weight	Cooled smoked meat	Loss		
			Cooler	Through cure	Through smoke			Cooler	Through cure	Through smoke
	Pounds	*Pounds*	*Per cent*	*Per cent*	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Per cent*	*Per cent*
1	200	191.5	−2.68	7.50	−4.25	152	138	−2.65	−2.63	−9.21
2	195	187.0	−3.08	7.69	−4.10	171	155	−2.82	−2.34	−9.35
3	154	148.0	−2.83	7.79	−3.89	225	205	−3.22	−2.22	−8.88
4	215	203.0	−2.80	6.97	−5.58	297	270	−2.95	−2.35	−9.09

MELTING POINTS OF LEAF AND BACK FATS

In Table VI only the average melting points of the various lots are shown. The individual variance from the average, not only in the melting points, but in the iodine values also, was so small that it was not deemed worth while to give each result. In this work the temperature at which the fats became transparent was taken as the melting point.

TABLE VI.—*Melting points of back and leaf fats*

Lot No.	Part 1		Part 2	
	Back fat	Leaf fat	Back fat	Leaf fat
	° *C.*	° *C.*	° *C.*	° *C.*
1	40.90	48.16	41.2	47.5
2	41.97	48.50	42.4	48.4
3	42.63	48.63	44.6	50.8
4	41.06	48.05	44.0	49.4

Very little difference is to be noted in the melting points of the fats from the various lots.

In part 1 there is a variance of only 0.58° in the leaf fat and 1.73° in the back fat. In part 2 the difference is slightly greater, there being a variance of 3.3° in the leaf fat and 3.4° in the back fat. In both part 1 and part 2 the melting points in the barley and tankage fed lots were consistently higher than in the other lots. This difference, however, is not sufficient to be of any great significance.

IODINE VALUES

The iodine values were run according to the Hanus method. From these the percentage of olein was calculated according to the table given in Lewkowitsch.[9]

[9] LEWKOWITSCH, J. CHEMICAL TECHNOLOGY AND ANALYSIS OF OILS, FATS, AND WAXES. Ed. 4, rewritten and enl., v. 3, p. 176 London. 1909.

TABLE VII.—*Iodine values of leaf and back fats*

Lot No.	Part 1				Part 2			
	Back fat		Leaf fat		Back fat		Leaf fat	
	Iodine value	Per cent olein	Iodine value	Per cent olein	Iodine value	Per cent olein	Iodine value	Per cent olein
1	66.08	73.36	55.3	61.39	65.1	72.27	57.5	63.83
2	61.5	68.24	55.68	61.79	63.7	70.72	54.6	60.57
3	65.9	73.15	55.76	61.90	62.4	69.27	52.3	58.06
4	64.6	71.71	56.84	63.09	62.0	68.83	53.4	59.28

Here, as in the determination of the melting points, very little difference can be noted between the various lots. In part 1 there is a variance of only 1.7 per cent olein in the leaf fat and 5.12 per cent in the back fat. In part 2 the widest variation was 5.77 per cent olein in the leaf fat and 3.44 per cent in the back fat.

DISCUSSION OF THE RESULTS

The individual variation in gains was greater in the pea-fed lots. Some of the hogs in the lots took to peas readily and did not tire of them, while others showed a tendency to go off feed frequently, influencing the uniformity of gains in the lots. Due to these variations, the pea-fed lots did not show as uniformly high a finish as did the other lots, and, in addition, tended to be paunchy. Both of these conditions somewhat lowered the dressing percentages. Barley, added to the pea ration, tended to overcome these conditions, the hogs having a better appetite, being less paunchy, and having a higher dressing percentage.

In the physical observation of carcasses in both part 1 and part 2 it was impossible to distinguish carcasses in one lot from those in another lot when of the same finish. The best carcasses in the pea-fed lots appeared in every respect equal to those in lots III and IV.

It would seem from these data and observations that one need not fear the production of soft pork when feeding peas, either alone or in combination. Commercial peas are ordinarily too high in price to be fed as the only grain ration. However, cull peas, which are quite comparable in feeding value to some of the standard feeds, are often available at reasonable figures.

Hogs fed on peas alone, either in the dry lot or on forage, tend to grow rather than fatten, and for this reason finish somewhat slower than when fed standard rations.

The feed requirement for 100 pounds of gain is in favor of the pea-fed lots, even though at times the pea-fed hogs did not have as vigorous an appetite as was evident in the other lots.

The quality of pork, when judged by physical observations of the carcasses, shrinkages in the curing process, melting points, and iodine values, tends to show that peas, when fed alone or with barley, compare favorably with such standard rations as barley and tankage, and corn and tankage.

GERMINATION OF FROZEN AND NONFROZEN WHEAT HARVESTED AT VARIOUS STAGES OF MATURITY[1]

By W. O. WHITCOMB and PAUL FRANCIS SHARP, *Montana Grain Inspection Laboratory and Department of Chemistry, Montana Agricultural Experiment Station, Bozeman, Mont.*

INTRODUCTION

In the northern part of the United States, and especially in the Rocky Mountain region and in western Canada, where the growing season is relatively short, spring wheat is frequently subjected to temperatures below freezing at immature stages of growth. Kernels threshed from frosted wheat may be recognized by the blistered or wrinkled appearance of the outer layers of the bran and by their green pigmentation. Usually the more immature the wheat at the time of frost the greater the number of green kernels. The green kernels may not be blistered.

Lugger (*10*)[2] attempted to distinguish between frosted and frozen wheat. He states:

> We see at once the important difference between frosted wheat and frozen wheat. In the former germination may take place in most cases; in the latter never, because the living substance of the seed, the protoplasm, is dead and can not be resurrected by any known means.

Harper (*7*) states more clearly the difference, saying:

> Frozen wheat is badly shrunken, has lost the normal translucent amber color, is of an opaque bronzed appearance, and has had the composition of its chemical constituents changed as well as the internal structure of its cells destroyed.
>
> Blistered (frosted) wheat retains the normal amber color, but has in many cases more gluten and protein and less starch than sound wheat, and is injured for milling on account of the bad condition of the hull. Only in extreme cases has there been any injury to the germ and its surrounding food, so that it is all right for seed, if well cleaned, except in some cases where frost has caused the injury because of the tardiness of the wheat to mature.

Green (*5*) tested the germination of frosted wheat in soil in the greenhouse. He found that the germination in the series of graded frosted wheats which he investigated ranged from 68 to 92 per cent. The lowest value found for 8 samples of wheat classed as chicken feed was 42 per cent. Some of these samples had been injured by both frost and rust.

Keffer (*8*) examined 13 samples of wheat. He determined the percentages of "plump," "slightly shriveled," and "much shriveled" kernels in each sample. Seven samples which contained 50 per cent or more of much shriveled kernels and averaged 72 per cent gave an average germination of 72 per cent in soil and 82 per cent between moist papers. Three samples with a content of much shriveled kernels ranging from 29 to 47 per cent gave an average germination of about 76 per cent in soil and 91 per cent between moist papers. The wheat which he reported as normal contained 5 per cent of much shriveled kernels and gave a germination of 82 per cent in soil and 99 per cent between moist papers.

[1] Received for publication May 2, 1925; issued December, 1925. Published with the approval of the director of the station.

[2] Reference is made by number (italic) to "Literature cited," p. 1188.

Atkinson, Whitlock, and Jahnke (*1*) investigated the seed value of frosted wheat. They separated into two parts each of 32 samples of wheat which contained a large percentage of frosted kernels, one containing only kernels showing frost injury and the other containing kernels showing no frost injury. The germination of these samples was tested in the field. The average germination of the frosted samples was 75 per cent and that of the nonfrosted 78 per cent. Their results show a greater number of heads per row and a higher yield from the frosted kernels. They state:

> The difference is not great enough to be very significant, yet it shows that kernels showing frost injury are not necessarily worthless for seed. It should be understood that grain may be entirely destroyed by frost, so far as its seed value is concerned, but this test suggests that all grain need not be discarded for seed purposes because it shows frost injury. The only safe plan is to have it tested before deciding either to use or discard it.

Atkinson and Jahnke (*2*) carried out further investigations on the germination of frosted wheat along somewhat the same line. The report of their experiments indicates that the frosted wheat showed a less germination than the nonfrosted wheat separated from the same samples.

Miss Lute (*11*) states that frosted wheat from San Luis Valley, Colo., showed low germination, but gives no definite data on the subject.

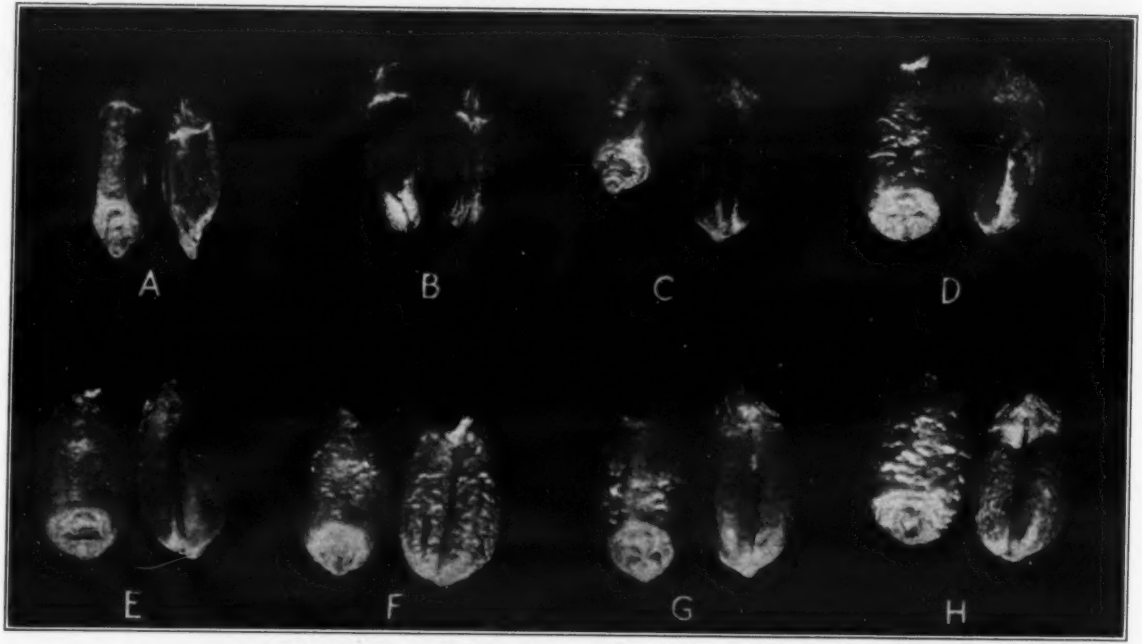
The effect of freezing temperatures produced by artificial means on the germination of seeds has been studied by a number of investigators. Detmer (*4*) states that air-dry wheat kernels can be subjected to temperatures of $-5°$ to $-10°$ C. without injuring their germination, while if the turgid kernels are subjected to these temperatures the germination is injured. Thiselton-Dyer (*13*) found that air-dry wheat kernels could be subjected to the temperature of liquid hydrogen for 1 hour without injuring their germination. Becquerel (*3*) subjected air-dry wheat kernels to liquid air for 130 hours and found that germination was unimpaired after this treatment.

EXPERIMENTAL DATA

A part of a 1923 crop of Marquis wheat was purchased from a farmer living near the Montana Agricultural Experiment Station. This wheat was grown under a system of dry farming. Portions of the wheat were harvested at intervals of two to four days during the development of the kernel. In order to restrict the amount of material flowing into the kernel after harvest, only the heads were gathered. Enough heads were obtained at a time to fill six 24-pound flour sacks. Three of these sacks were placed in the hardening room of an ice-cream manufacturing plant for 48 hours, after which time they were spread on the floor of a large room to dry. The other three sacks picked at the same time were at once spread on the floor to dry. The temperature of the hardening room ranged between $-20°$ and $-28°$ C. After the heads became dry they were threshed.

The moisture content of the kernels was determined at the time of harvest. The values obtained are given in Table I. The weight per kernel was calculated from the weight of 1,000 kernels. Typical frozen and nonfrozen kernels at four stages of development were photographed (pl. 1). Estimating the age of the kernels from the

data given by Sharp (*12*) for the development of Marquis wheat obtained in a similar experiment the previous year, it is probable that the kernels in samples 131 and 132 (see Table I) are about 13 days old. In the previous year (Table I of the paper by Sharp) kernels 13 days old contained 70.7 per cent moisture and weighed 7.9 mgms., while sample 131 contained 69.4 per cent moisture at the time of harvest and the dry weight per kernel was 7.7 mgms. This estimated age of the kernel is probably correct to within one or two days. The kernels representative of sample 131, Plate 1, A, have the yellow color of mature wheat, the kernels from the sample 132, Plate 1, B, which was collected at the same stage of maturity but which was frozen before drying, are entirely green in color. Samples 137 C and 138 D in Plate 1 were collected 12 days later and therefore are approximately 25 days old. The frozen kernels, 138, still show some green color, and blistering of the outer bran layers is apparent. Samples 141, Plate 1, E, and 142, Plate 1, F, were approximately 29 days old; at this stage of development no green kernels were found in the frozen sample; the blistering of the outer layers of the bran was greatest during this period of development. Sample 149, Plate 1, G, and sample 150, Plate 1, H, were approximately 38 days old, and blistering of the frozen kernels was still marked. Samples 149 and 150 were collected five days after the time the farmer considered the best for cutting the main part of his field of wheat. Thus the farmer decided to cut his wheat when the kernels were approximately 33 days old. Sample 152 also showed marked blistering. It is thus apparent that blistering may be produced by severe freezing even when the moisture content of the wheat is 34 per cent or less. Possibly if the freezing temperature had been less severe blistering might not have occurred at such a low moisture content. Farmers frequently believe that their wheat is safe from frost damage as soon as it is in the shock. Whether or not wheat is safe from frost damage probably depends on the moisture content of the kernel and the freezing temperature and its duration. Additional data on this series of wheat are given by Sharp (*12*) and will not be repeated here.



Kernels of frozen and nonfrozen wheat harvested at various stages of maturity

A.—Sample No. 131, nonfrozen, approximate age, 13 days
B.—Sample No. 132, frozen, approximate age, 13 days
C.—Sample No. 137, nonfrozen, approximate age, 25 days
D.—Sample No. 138, frozen, approximate age, 25 days
E.—Sample No. 141, nonfrozen, approximate age, 29 days
F.—Sample No. 142, frozen, approximate age, 29 days
G.—Sample No. 149, nonfrozen, approximate age, 38 days
H.—Sample No. 150, frozen, approximate age, 38 days

Germination tests as described by Whitcomb (*14*) were made on November 24 and December 21, 1923, and November 22, 1924, by the alternating-temperature method. This test, as carried out, consisted in placing 100 kernels between pieces of moist blotting paper and keeping them for 18 hours at 20° C., and then raising the temperature to 30° C. for six hours, and then lowering it to 20° C. for 18 hours, etc. On December 21, 1923, the germination was determined also by the ice-box method. In this method 100 kernels were placed between moist blotting papers, and kept continuously in the ice box at 4° to 6° C. for five days, at the end of which time the wheat was treated by the alternating-temperature method as described above. The tests were all carried out in duplicate. The results are given in Table I.

TABLE I.—*Marquis wheat: Germination of frozen (temperature −20° to −28° C.) and nonfrozen wheat harvested at various stages of maturity*

[Harvest began Aug. 9, 1923, when the kernels were about 13 days old. The germination tests were all run on duplicates of 100 kernels. Where 0.5 per cent occurred in the average it was added as 1 per cent]

Laboratory No.	Approximate age of kernel	Moisture at time of harvest	Weight per kernel, moisture-free	Germination			
				Nov. 24, 1923, alternating temperature 20° to 30° C., 9 days	Dec. 21, 1923		Nov. 22, 1924, alternating temperature 20° to 30° C., 6 days
					Alternating temperature 20° to 30° C., 6 days	Ice box, 5 days, alternating temperature 3 days	
	Days	*Per cent*	*Mgs.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
131, nonfrozen	13	69.4	7.7	98	95	99	91
132, frozen	13	69.4		1	2	0	0
133, nonfrozen	17	62.5	14.0	98	99	99	96
134, frozen	17	62.5		3	5	3	2
135, nonfrozen	21	56.2	19.5	99	100	100	97
136, frozen	21	56.2		2	3	3	1
137, nonfrozen	25	50.6	25.3	99	100	99	98
138, frozen	25	50.6		57	72	62	35
139, nonfrozen	27	46.5	25.7	99	99	98	94
140, frozen	27	46.5		42	60	80	22
141, nonfrozen	29	46.5	26.8	99	100	98	96
142, frozen	29	46.5		17	66	63	9
143, nonfrozen	31	45.0	28.5	99	100	93	89
144, frozen	31	45.0		10	84	89	0
145, nonfrozen [1]	33	43.5	29.9	98	99	98	98
146, frozen	33	43.5		42	77	85	27
147, nonfrozen	35	38.7	30.7	99	100	100	93
148, frozen	35	38.7		42	80	80	32
149, nonfrozen	38	34.1	30.2	100	100	99	95
150, frozen	38	34.1		72	89	88	63
151, nonfrozen	41		31.0	99	100	99	98
152, frozen	41			92	98	97	82

[1] Main part of field harvested.

The effect of freezing the kernels on their germination on November 24, 1923, is apparent in all of the stages of development studied. The germination of the nonfrozen samples was very high throughout the whole range. The germination tests carried out about a month later show a great increase in the germination of those frozen samples which had a moisture content of 50 per cent or less at the time of freezing. After aging for more than a year the germination of the frozen samples had decreased markedly, while the nonfrozen samples

decreased in germination only slightly or not at all. Table I shows very clearly the pronounced effect of aging on the germination of frozen wheat, the germination being at first relatively low, increasing to a maximum, and then decreasing, so that at the end of a year the germination is again relatively low. The germination of the wheat which was more mature at the time of frost was less affected by freezing than was the more immature wheat. It would seem from an examination of Table I that if frosted wheat is to be used for seed it should be tested for germination immediately before seeding. Comparisons of the effects produced by subjecting seeds to freezing temperatures should include aging experiments.

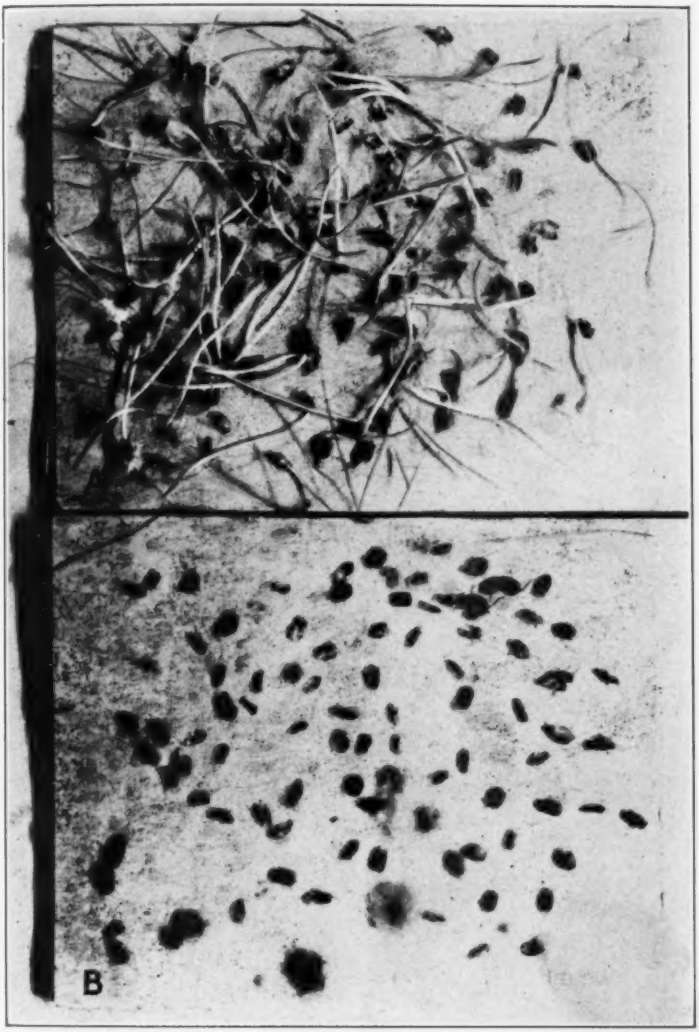
Kiesselbach and Ratcliff (*9*) studied the effect on germination of subjecting immature corn to freezing temperatures. Their results show clearly that at a given moisture content the injury increases as the freezing temperature is lowered, and that "death from freezing is directly related to the moisture content of the kernel and also to the duration of the exposure to cold."

The wheat used in this investigation was subjected to freezing temperatures considerably lower than wheat would normally encounter in the field. These low temperatures were chosen intentionally, for the reason that if no effect was produced under these conditions then no effect would be expected under less severe ones. The results indicate the desirability of investigating the effect of less severe freezing temperatures.

Attention is called to the almost complete germination of the nonfrozen wheat at all of the stages of development studied. Even when the kernel was only approximately 13 days old germination was practically complete. The investigations of Harlan and Pope (*6*) on the germination of barley harvested at different stages of growth are of interest in this connection. These investigators hand-pollinated Hannchen barley so that they knew the exact age of the kernel to within one hour. They found no germination on the fourth day, but on the fifth day 9 out of 10 kernels germinated. The dry matter content of the Hannchen barley at 6 days of age was given as about 5 mgms. Kiesselbach and Ratcliff (*9*), in studying seed corn production, found that "the power of germination is attained in about 20 days after fertilization."

The germination tests carried out by the ice-box method December 21, 1923, gave only slightly different results from the alternating-temperature method.

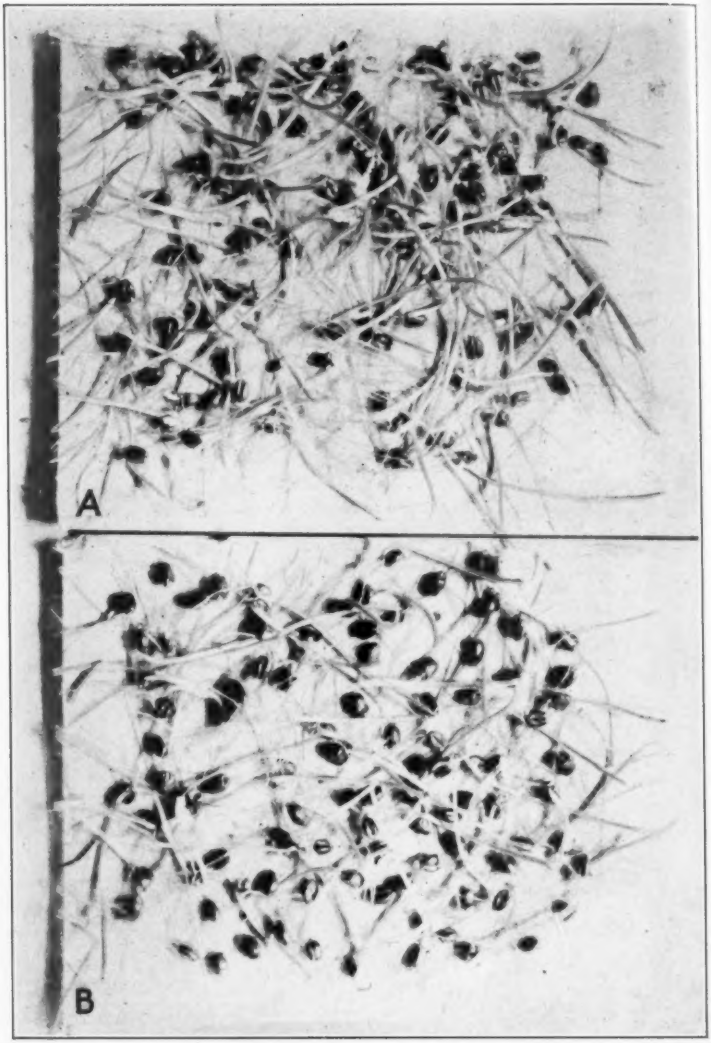
Photographs of the germinated kernels from the test of December 21, 1923, using the alternating-temperature method for samples 131 and 132, are given in Plate 2; for samples 137 and 138, in Plate 3; and for samples 149 and 150, in Plate 4. These plates give an indication of the probable strength of the plant produced. There is apparently a greater development in the more mature samples.



Germination tests of wheat made December 21, 1923, by the alternating-temperature method

A.—Sample No. 131, nonfrozen wheat germination, 95 per cent
B.—Sample No. 132, frozen wheat germination, 2 per cent

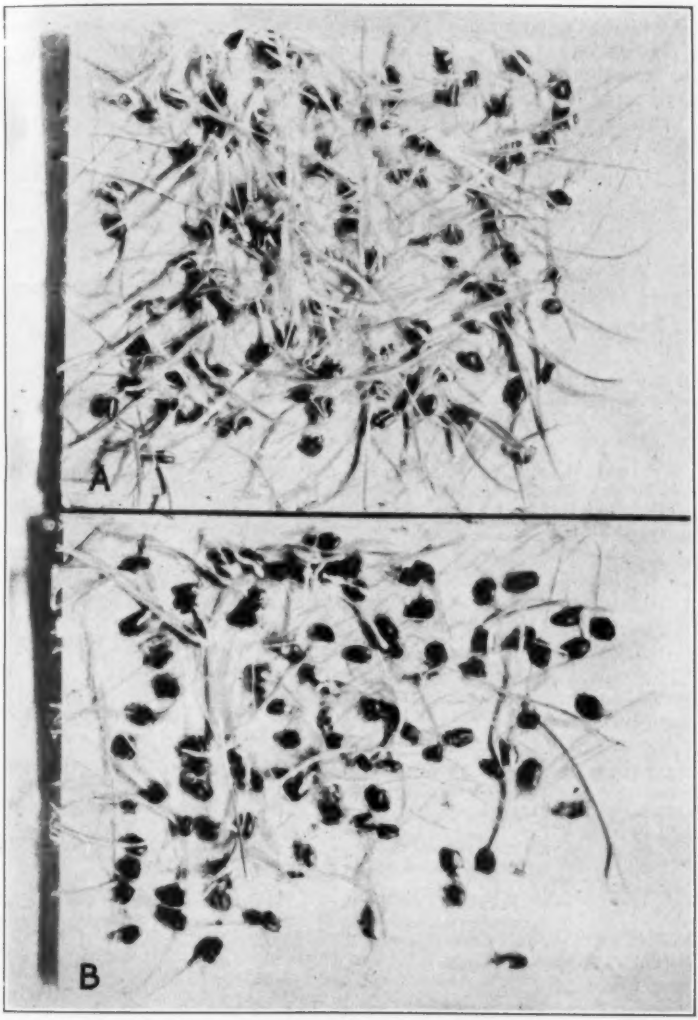
Approximate age of kernels, 13 days



Germination tests of wheat made December 21, 1923, by the alternating-temperature method

A.—Sample No. 137, nonfrozen wheat germination, 100 per cent
B.—Sample No. 138, frozen wheat germination, 72 per cent

Approximate age of kernels, 25 days



Germination tests of wheat made December 21, 1923, by the alternating-temperature method

A.—Sample No. 149, nonfrozen wheat germination, 100 per cent
B.—Sample No. 150, frozen wheat germination, 89 per cent

Approximate age of kernels, 38 days

CONCLUSIONS

Very immature wheat shows almost perfect germination.

Freezing impairs the germination of wheat less the more mature the wheat is at the time of freezing.

The germination of frosted wheat is greatly affected by aging. The germination is at first relatively low, increases with time to a maximum, and then decreases to a low degree.

Frosted wheat should be tested for germination immediately before seeding.

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THE INFLUENCE OF NITRATE NITROGEN UPON THE PROTEIN CONTENT AND YIELD OF WHEAT[1]

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REVIEW OF LITERATURE

The factors which influence the formation of protein in wheat have been studied by several investigators. From their results two theories appear worthy of consideration, (1) that the moisture content of the soil during the growing period is the controlling factor in protein formation, a high moisture content generally resulting in the production of wheat of low protein content, and (2) that the quantity of nitrate nitrogen present in the soil during the growth of the wheat is the most important factor in the production of a high protein content. No attempt will be made in this paper to give a complete review of the literature published.

INFLUENCE OF MOISTURE UPON PROTEIN FORMATION

Most of the results of the work of the early investigators indicate that moisture is the controlling factor in protein formation, an opinion shared by most farmers in the irrigated sections of Montana. The general opinion seems to be that when the moisture is increased a wheat of low protein content is produced. Thatcher (*6*)[2] found that certain factors of climate, such as rainfall and temperature, have a decided influence on protein formation, and he concluded that the protein content of wheat in eastern Washington decreases with an increase of rainfall. He also calls attention to the length of the growing period as a factor in protein production. Widtsoe and Stewart (*7*) found that a variation in the quantity of irrigation water caused a difference in the protein content of wheat. From their analytical data they concluded that the protein content is lowered with an increase of irrigation water. Harris (*2*), working in the greenhouse where controlled conditions were possible, found that the percentage of nitrogen in both grain and straw was influenced by the quantity of moisture in the soil. The highest protein content was obtained from wheat grown in soil of low moisture content, and the lower protein content from soil containing the higher percentages of moisture. Harris found further that fertilizers high in nitrogen brought about an increase in the nitrogen content of wheat crops.

INFLUENCE OF NITRATE NITROGEN ON PROTEIN FORMATION

Headden (*3*) conducted an extensive investigation of the factors which influence protein formation, and he was among the first to make a study of the available nitrogen present in the soil during plant growth. In addition, he studied the influence of a varying

[1] Received for publication April 30, 1925; issued December, 1925. Published with the approval of the director of the station.

[2] Reference is made by number (italic) to "Literature cited," p. 1199.

quantity of irrigation water applied to the land during the growing season. In speaking of the wheat grown in Colorado on land irrigated with 1 and with 2 feet of water, he states that no results were secured which showed conclusively that the different amounts of water applied made any difference in the weight of the wheat per bushel or in the composition of the grain. Jones, Colver, and Fishburn (*4*) also made a study of the factors influencing wheat protein formation. In their conclusions they state that growers and millers are wrong in assuming that low protein wheats necessarily result from the practice of irrigation and that, as a matter of fact, irrigation is not the controlling factor in determining the protein content of the harvested grain. They state further that a better quality of grain is possible when wheat is brought into rotation with alfalfa or red clover, since the activity of nitrifying organisms in the sod of these legumes when turned under provide a substantially larger supply of available nitrogen for growing wheat plants.

Neidig and Snyder (*5*) made an extensive investigation of the factors which influence the formation of protein. Their studies were confined to pot experiments with different types of soil and the application of different fertilizers. They found that the available nitrogen in the soil directly affected both the quantity of protein in the grain and the yield of wheat under the conditions of their experiments. They state that climate also plays an important part in the quality and yield of wheat.

In some of the publications on the influence of moisture upon protein formation there seems to be a lack of data relative to the quantity of nitrates in the soil during the period over which the experiments extended.

EXPERIMENTS IN MONTANA

From 1911 to 1917, inclusive, an investigation was conducted at the Montana Experiment Station for the purpose of studying the factors which influence nitrate formation in the soil. As will be shown, the results obtained have a direct bearing on the subject of protein formation. The experiments were made in a dry-land section of Gallatin Valley having an average rainfall of nearly 20 inches. The soil is a silt loam, classified as Yakima silt loam. It is of alluvial origin, at one time the bottom of an old lake bed, and is especially rich in all of the plant food elements. The total nitrogen averaged about 0.25 per cent. This soil was cultivated first in 1910, when it was laid out in twentieth-acre plots. The data used in this article are from plots cropped continuously with both winter and spring wheat and from plots growing winter and spring wheat under alternate fallow and crop. The plots growing continuous crops of wheat were plowed either in the fall or early spring. The plots summer-fallowed were plowed in the early spring and cultivated throughout the growing season for the purpose of conserving moisture and keeping the land free from weeds.

SAMPLING THE SOIL

Soil samples were taken about every two weeks for the purpose of determining the moisture content and the quantity of nitrates and nitrites present. These samples represented the first, second, third,

fourth, and fifth feet of soil, except the first sampling in the spring, the midsummer sampling, and the last sampling in the fall when samples were taken to a depth of 10 feet. The crops were harvested in the autumn and a careful record was made at the time of threshing of the pounds per plot of both grain and straw. Samples of both were taken from all plots and analyzed for total nitrogen.

TABLE I.—*Yield in pounds of grain and straw, percentage of nitrogen in the crop, pounds of nitrogen removed by the crop, average percentage of moisture found in the first 3 feet of soil during the growing season, the average parts per million of nitrate nitrogen, and the concentration of the nitrate nitrogen in the soil solution*

PART 1. WINTER WHEAT—CONTINUOUS CROPPING

Year	Plot	Yields, in pounds		Percentage of nitrogen in—		Pounds of nitrogen removed by—		Total nitrogen removed	Percentage of water in first 3 feet of soil	P. P. M. nitrate nitrogen in first 3 feet of soil	Concentration of nitrate nitrogen in soil solution	Dates of sampling	
		Grain	Straw	Grain	Straw	Grain	Straw					First	Last
1911	1	95.0	259	2.30	.....	2.18	.....	.....	15.55	2.05	11.3	May 2	July 11
1912	1	102.6	149	2.30	0.44	2.36	0.66	3.02	16.34	6.38	33.6	Apr. 29	July 26
1913	1	65.2	118	1.78	.40	1.16	.47	1.63	12.76	2.06	14.2	May 6	July 28
1914	1	71.3	57.9	2.08	.59	1.48	.34	1.82	15.22	2.23	12.7	May 9	July 21
1915	1	82.7	131.3	2.13	.34	1.76	.45	2.21	20.58	2.26	9.1	May 10	July 20
1916	1	72.2	94	1.92	.43	1.38	.40	1.78	20.05	2.03	8.4	Apr. 26	Aug. 7
1917	1	21.8	35	2.10	.67	.46	.23	.69	18.49	2.14	9.8	May 8	July 17
Average		72.9	120.7	2.09	.48	1.54	0.42	1.86	17.00	2.73	14.2	.....	.....

SPRING WHEAT—CONTINUOUS CROPPING

1911	2	61.8	128.0	1.50	0.69	0.93	0.88	1.84	16.34	2.51	13.2	May 16	Aug. 15
1912	2	101.7	150.0	1.91	.34	1.94	.51	2.47	15.91	4.29	23.2	May 21	Sept. 4
1913	2	66.2	123.7	1.98	.42	1.31	.52	1.83	13.91	1.95	12.3	May 23	Aug. 7
1914	2	38.4	104.5	2.66	.63	1.02	.66	1.68	16.25	2.04	10.8	June 3	Aug. 17
1915	2	50.0	117.6	2.12	.58	1.06	.68	1.75	19.25	1.85	8.0	May 24	Aug. 24
1916	2	77.0	87.0	2.02	.28	1.55	.24	1.85	20.02	2.25	9.4	May 23	Aug. 7
1917	2	30.0	57.0	2.09	.57	.62	.32	.95	16.39	1.48	7.7	May 24	Aug. 9
Average		60.7	109.7	2.04	.50	1.20	.54	1.78	16.87	2.34	12.1	.....	.....

PART 2. WINTER WHEAT—ALTERNATE FALLOW AND CROP

1911	12	103.5	284.0	2.30	0.51	2.38	1.45	3.83	15.35	4.06	22.9	May 6	July 15
1912	16	158.6	316.3	2.36	.53	3.74	1.68	5.42	16.34	12.68	66.6	May 9	July 29
1913	12	149.8	206.4	2.40	.44	3.60	.91	4.51	15.26	5.69	32.4	May 9	July 28
1914	16	105.0	326.8	2.70	.57	2.84	1.86	4.72	15.76	2.13	11.7	May 6	July 22
1915	12	156.3	342.0	2.06	.32	3.22	1.09	4.31	19.34	2.43	10.5	May 13	July 12
1916	16	117.0	161.5	2.63	.51	3.08	.82	3.90	22.49	5.17	18.8	May 2	Aug. 7
1917	12	53.2	118.8	2.90	.76	1.54	.90	2.45	17.98	4.33	20.4	May 8	July 18
Average		120.5	250.8	2.48	.52	2.90	1.24	4.16	17.50	5.21	26.2	.....	.....

SPRING WHEAT—ALTERNATE FALLOW AND CROP

1911	17	99.8	190.0	2.30	0.51	2.29	0.97	3.26	17.03	5.75	28.8	May 16	Aug. 17
1912	13	145.3	210.9	2.94	.78	4.27	1.65	5.92	14.43	7.79	47.3	May 23	Sept. 4
1913	17	129.7	259.3	2.75	.41	3.57	1.06	4.62	13.91	5.57	35.1	May 23	Aug. 7
1914	13	61.4	186.0	3.28	.89	2.01	1.65	3.66	17.59	4.08	19.5	May 21	Aug. 3
1915	17	91.8	284.4	2.64	.64	2.42	1.82	4.25	19.25	3.84	16.7	May 26	Aug. 24
1916	13	117.8	172.0	2.85	.46	3.35	.79	4.14	21.01	7.79	30.6	May 23	Aug. 5
1917	17	40.8	73.0	2.84	.69	1.16	.51	1.67	16.39	7.03	37.0	May 24	Aug. 15
Average		98.1	196.5	2.80	.63	2.72	1.21	3.93	17.09	5.98	30.7	.....	.....

Table I gives the yield in pounds of the wheat and straw. It also shows the percentage of nitrogen in the crop and the total number of pounds of nitrogen removed by the crop. The average percentage of moisture found in the first 3 feet of soil during the growing season, the average parts per million of nitrate nitrogen, and the concentration of the nitrate nitrogen in the soil solution are also included. The moisture and nitrate data are based on a 3-foot average on the assumption that that found in the soil at greater depths has but little influence upon yield or quality of wheat. An inspection of part 1 of this table shows a variation in yields which can hardly be attributed to a difference in the moisture content of the soil, or can it be attributed entirely to a variation in the different amounts of available nitrogen present. Table II, giving monthly precipitation and mean monthly temperatures, shows a variation in both of these factors which must be considered. While both moisture and nitrates affect quality and yield, there are other factors, such as temperature, sunshine, and length of growing season, which must also be considered. Although a comparison can not be made of the yield and protein content of the grain and straw in relation to the moisture found in the soil for the different years on the continuously cropped and alternate fallow and cropped plots, yet it is but fair to assume that comparisons can be made for the same year when climatic conditions are necessarily the same.

TABLE II.—*Monthly precipitation and monthly mean temperature records for Bozeman, Mont., from April, 1911, to August, 1917*

Year	Monthly precipitation						Monthly mean temperature				
	April	May	June	July	August	Total	April	May	June	July	August
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
1911	1.57	3.56	3.06	0.84	1.52	10.55	38.5	47.4	58.7	60.8	58.3
1912	3.59	2.66	2.69	1.91	1.63	12.48	31.3	49.2	58.7	59.9	58.4
1913	1.65	2.54	3.19	2.17	1.80	11.33	42.6	49.0	58.1	60.1	64.3
1914	2.02	2.05	3.54	1.28	.11	9.00	40.6	50.6	55.4	65.1	61.8
1915	2.60	3.67	4.44	3.91	.38	15.00	48.6	46.8	51.4	57.3	64.2
1916	2.10	2.99	2.33	1.58	1.38	10.38	40.8	43.0	53.1	64.2	60.9
1917	1.72	2.37	2.46	.36	.53	7.44	35.4	46.9	55.1	68.8	63.4
Average	2.17	2.83	3.10	1.72	1.05	10.88	41.1	47.5	55.8	62.3	61.6
Normal *	1.93	2.82	2.88	1.32	.93	9.88	41.3	49.4	57.2	63.7	62.9

* 35-year average.

RESULTS FROM WINTER WHEAT

By referring to Table I it will be seen that the average yield of winter wheat grown on the continuously cropped plots was 72.9 pounds; the average yield of winter wheat on the alternate fallow and crop plots was 120.5 pounds. The average moisture content on the continuously cropped plots, to a depth of 3 feet, was 17.00 per cent; the moisture content on the alternate fallow and crop was 17.57 per cent. The average nitrogen content of the grain grown on the continuously cropped plots for the seven years was 2.09 per cent; that grown on the alternate fallow and crop plots was 2.48 per cent, a decided increase over the continuously cropped plots which had a lower percentage of moisture in the soil.

RESULTS FROM SPRING WHEAT

The plot growing spring wheat, continuously cropped, also shows a lower moisture content of the soil to a depth of 3 feet and a lower protein content of the grain. Here again the soil containing the higher percentage of moisture produced the largest yields and a grain of higher protein content. In studying Table I it must be observed that in each year the plots containing the highest percentages of available nitrogen produced wheat of a higher protein content, one exception only being noted. This occurred in 1915 when the alternate fallow and crop plot produced grain having a nitrogen content of 2.06 per cent and the continuously cropped plot produced grain having a nitrogen content of 2.13 per cent. The results of that year's experiment thus show but very little difference in the available nitrogen, though the difference is slightly in favor of the alternate fallow and crop. An examination of the writer's data indicates that in that year the average available nitrogen in the first foot of soil was 2.24 parts per million for the continuous cropping and 2.19 for the alternate fallow and crop plot. It is possible that the available nitrogen in the first foot exerted the greatest influence on protein formation, but the difference in the quantity of nitrates in the soil was too slight to account for the difference in amount of protein formed in the wheat. The fact that the alternate fallow and crop plot gave not only a higher average yield but also a higher average percentage of nitrogen content in both grain and straw shows at least the influence which available nitrogen exerts on the crop and its composition.

MOISTURE AND NITRATES IN SOIL AS RELATED TO YIELDS AND PROTEIN CONTENT

Winter Wheat

In order to present more clearly the influence of moisture and nitrate nitrogen in the soil upon yield and protein formation of wheat, the data have been charted showing the difference in the moisture content of the soil at different periods of plant growth and also the different amounts of nitrate nitrogen for the same periods (figs. 1 and 2). Figure 1 shows a variation of less than 1.5 per cent in the moisture content of the soil from the time the winter wheat began to grow in the spring until it was ready to harvest. The greatest variation occurred at the time of the second sampling, May 23, and before the winter wheat had made sufficient growth for taking moisture from the soil at its maximum rate. After the sampling on this date, there is no period in the growth of the wheat when the moisture content varies enough to account for any difference in the yield or composition of the grain. These differences must then be explained by some other cause. Figure 2 indicates that there is a wide variation in parts per million of nitrate nitrogen in the soil for the same plots continuously and alternately cropped. The continuously cropped plots show a lower percentage of nitrate nitrogen at each sampling than do the alternate fallow and crop. The very fact that both grain and straw contain a higher percentage of nitrogen suggests very strongly that the difference in the quantity of nitrate nitrogen present in the soil is also largely responsible for the difference in yields.

Spring Wheat

For spring wheat Figure 1 shows but little difference in the moisture content of the plots continuously cropped and those growing spring wheat alternating with fallow. The difference up to June 28 is not sufficient to cause any difference in the rate of growth. It must be noted, however, that after June 28 there was a more decided drop in the moisture content of the alternate fallow and crop plots than in the plots continuously cropped. It is quite possible that the greater

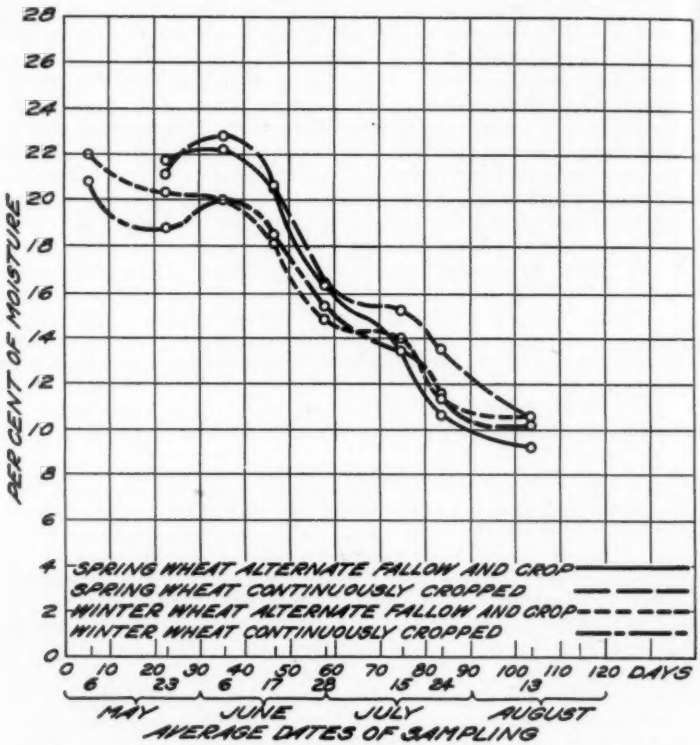

Fig. 1.—Moisture content of the soil in several plots at different periods of plant growth

growth of the spring wheat, as shown by the yields, brought about this change. If this be true, then it is quite certain that some factor in addition to moisture was responsible for the difference in plant growth. This difference can not be attributed to any difference in climatic conditions. A study of Figure 2 shows that the summer-fallowed plot contained much more nitrate nitrogen than the plot continuously cropped. In Table III the plot yields are calculated to bushels per acre, and these calculations show that the average of seven years' yield of winter wheat is 24½ bushels on the continuously cropped land and 40⅙ bushels on the alternate fallow and crop land.

The seven-year average on continuously cropped land shows a yield of 20¼ bushels of spring wheat as against 32⅕ bushels on the alternate fallow and crop land. The average protein content of both spring and winter wheat produced on the continuously cropped land is much lower than it is in the spring and winter wheat produced on the alternate fallow and crop.

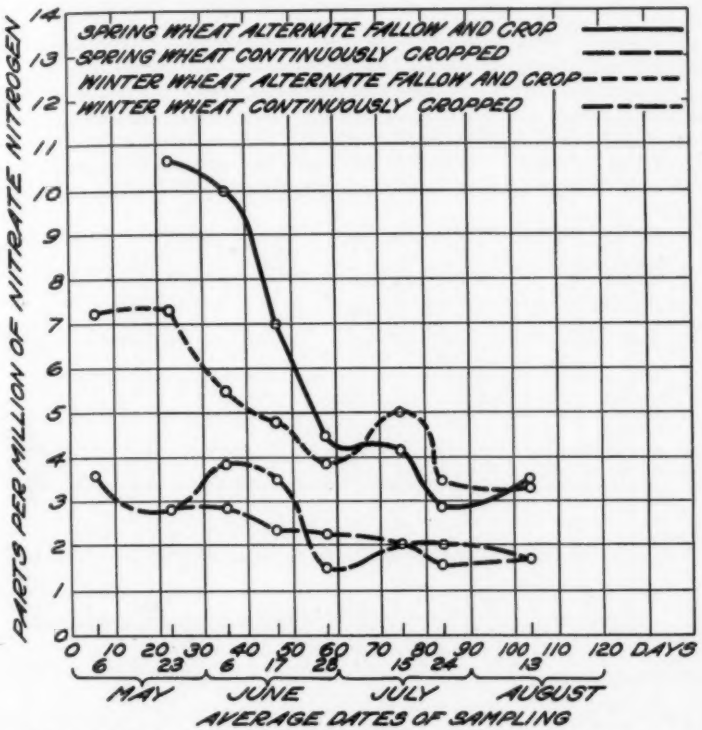
SPRING WHEAT ALTERNATE FALLOW AND CROP
SPRING WHEAT CONTINUOUSLY CROPPED
WINTER WHEAT ALTERNATE FALLOW AND CROP
WINTER WHEAT CONTINUOUSLY CROPPED
PARTS PER MILLION OF NITRATE NITROGEN
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
0 10 20 30 40 50 60 70 80 90 100 110 120 DAYS
6 23 6 17 28 15 24 13
MAY JUNE JULY AUGUST
AVERAGE DATES OF SAMPLING

FIG. 2.—Nitrate nitrogen found in the soil of several plots at different periods of plant growth

TABLE III.—*Yield per acre and protein content of wheat on plots continuously cropped and plots alternately fallow and cropped (seven-year average)*

	Plots continuously cropped		Plots alternately fallow and cropped	
	Bushels	Percentage of protein	Bushels	Percentage of protein
Winter wheat	24½	11.91	40¼	14.13
Spring wheat	20¼	11.63	32⅕	15.90

From a study of the graphs showing moisture and nitrates it seems hardly possible that any of the differences which appear in the

moisture content of the soil to a depth of 3 feet could be the controlling factor in bringing about the difference both in yield and in protein formation. The fact that there is more available nitrogen in the summer-fallowed plots than in those continuously cropped indicates quite strongly that the available nitrogen in the soil is the more important factor.

EFFECT OF CLIMATIC CONDITIONS

The yearly variations in yields and percentages of nitrogen found in grain and straw are undoubtedly influenced by climatic conditions. An inspection of Table II shows that the year 1917 was the driest year recorded during the seven-year investigation, and it shows also that the temperatures for July and August of that year were considerably above the average. A lack of moisture accompanied by high temperatures during these months was undoubtedly the controlling factor

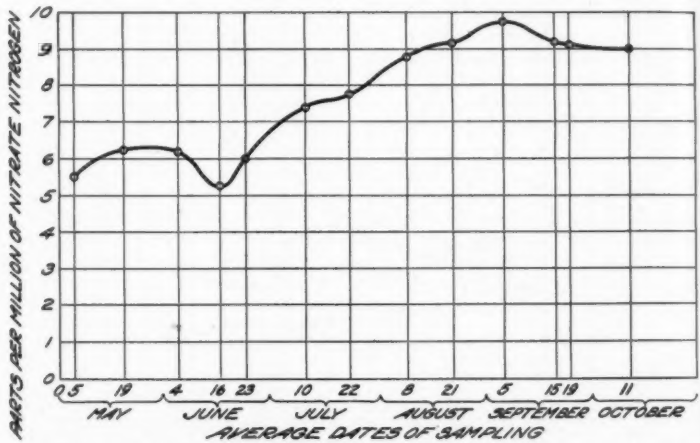

FIG. 3.—Nitrate nitrogen found in the soil of four summer-fallow plots at different periods of plant growth

in producing small yields. The yields for 1914 were quite certainly affected by a low precipitation during July and August and a high temperature during July. The year 1915 gave, in general, very good yields. The precipitation for the months of June and July was considerably above the average, but the temperature for the same months was below normal. These conditions were favorable for plant growth and were important factors in producing larger yields that year. There does not seem, however, to be any constant ratio between the protein content of the wheat and the yield on the continuously cropped plots for the different years, nor is there any decided difference in the protein content of the wheat grown on the alternate fallow and crop plots in favor of the dry years. The most pronounced difference was with spring wheat in 1914.

The data on the formation of nitrate nitrogen in the soil, given in Figure 3, show that there was a decided loss in June in the first 3 feet of soil. It is possible that the ground water carried some of the

nitrates below this depth. Table IV shows the average loss of nitrate nitrogen for two plots at the time when the greatest loss shown in Figure 3 occurred. This, however, represents a loss of nitrate nitrogen to a depth of 5 feet. Unpublished data of the writer show that there was no leaching of nitrates below the fifth foot for the years 1911, 1912, 1913, and 1917. A slight leaching was noted in the years 1914, 1915, and 1916. This leaching caused an increase in moisture of from 1 to 2 per cent in the fifth foot. It is hardly possible, however, that this slight degree of leaching brought about the reduction apparent in Table IV. The table shows a gain in nitrate nitrogen between the first and second sampling for the year 1916. It must be noted, however, that on May 23, 1.35 parts per million of nitrate nitrogen was found in the soil, the smallest amount shown in the table.

TABLE IV.—*Loss or gain in parts per million of nitrate nitrogen in the soil to a depth of 5 feet.*

Year	Plot No.	Date of first sampling	Parts per million of nitrate nitrogen	Date of second sampling	Parts per million of nitrate nitrogen	Percentage loss	Loss in pounds per acre to a depth of 5 feet
1911	13 and 16	June 2	5.00	June 13	2.68	46.1	40.6
1912	12	June 3	6.58	June 12	5.33	19.0	21.9
1913	13 and 16	...do....	11.61	July 1	9.07	18.2	44.4
1914	12 and 17	May 21	7.68	June 11	4.86	31.2	49.3
1915	13 and 16	May 26	11.55	June 9	6.62	43.8	86.3
1916	12 and 17	May 23	1.35	...do....	2.61	+37.6	[a] 22.1
1917	13 and 16	May 24	6.61	June 13	5.49	14.1	19.6

[a] Gain.

NOTE.—The percentages gain or loss of nitrate nitrogen given in this table were obtained by taking an average of the percentages of two plots; 17,500,000 pounds was the weight of the soil used in calculating the loss per acre.

Meteorological data, not included in this article, show that 0.97 inch of precipitation fell as snow between May 9 and May 13. Between May 19 and May 22 there was 1 inch of rain. This cold, wet spell was responsible for the reduction of nitrates prior to the sampling on May 23, a fact which is clearly evident from unpublished data showing that on May 1 there had been 3.97 parts per million of nitrate nitrogen. This is one year when the reduction took place before the first date of sampling, shown in Table IV.

If such conditions occur in soil receiving a monthly precipitation of something like 3 to 4 inches, it is reasonable to suppose that irrigation would have a decidedly greater influence in bringing about a loss of nitrogen either by carrying the nitrates into some porous substratum where they would be lost or, if there is no such substratum, to depths where denitrification would occur. It is altogether probable that irrigation favors even a greater reduction in the amount of available nitrogen than takes place under normal rainfall conditions. Hall (*1*) states that—

> a comparison of the nitric nitrogen in the first 5 feet of a nonirrigated cultivated soil with that in an irrigated cultivated soil shows the nonirrigated soil of the same type to be much superior in nitrate content, although the irrigated soil does not get sufficient water to carry the nitrates to the fourth foot.

If irrigation such as that maintained by Hall caused a decrease in nitrate nitrogen formation, it is quite certain that excessive irrigation would cause a greater decrease. Spring rains also reduce the quantity of nitrate nitrogen in the soil. It is quite possible that an increase in moisture, either by natural causes or by irrigation, decreases the protein content of wheat indirectly through its reduction of the nitrates in the soil.

The difference in the yields obtained from continually cropped and summer-fallowed plots corresponds very closely to that obtained by farmers on the dry land in the same locality. Even in the irrigated sections of Gallatin Valley the farmers find a wide difference in the yields of grain when grown continuously or when grown on summer-fallowed land. Nor can the difference in the grain yields obtained by farmers on irrigated land by these two methods of cropping be attributed to a difference in moisture conditions of the soil. The farmers of the irrigated districts abandoned the general custom of alternate fallow and crop several years ago and adopted a system of rotation with clover or some other legume as one of the crops. This practice has kept up the organic content of the soil and also the yields of grain, in marked contrast to the results obtained in former years when some farmers attempted to grow grain continuously.

CONCLUSIONS

Plots alternated with fallow and crop produce more spring and winter wheat per acre than plots of the same soil type cropped continuously.

Plots alternated with fallow and crop contained on an average more moisture to a depth of 3 feet than the plots cropped continuously. The greatest difference in moisture content occurred with spring wheat when the plants were making their most rapid growth. With winter wheat the greatest difference in moisture content occurred at a time when the soil was well supplied with moisture and before the plants were making their most rapid growth.

Plots alternated with fallow and crop contain more nitrate nitrogen during the cropped year than those cropped continuously. This extra supply of available nitrogen undoubtedly accounts for the alternate fallow and cropped plots producing straw and grain of a higher nitrogen content than those cropped continuously.

Nitrate nitrogen in the alternate fallow and crop plots shows a greater decrease in parts per million in the cropped years than does the continuously cropped plots. This decrease started before the wheat plants were large enough to take up much plant food from the soil and must be explained largely on the theory of leaching. A continuation of the decrease may be explained on the supposition that the wheat plants were taking nitrates from the soil faster than they were formed.

The higher yields and protein content of wheat grown on the alternate fallow and crop plots over those on plots cropped continuously can not be explained from the standpoint of moisture. The fact that the fallow plots always produced larger yields and grain of a higher protein content than the plots cropped continuously indicates that nitrate nitrogen is certainly a factor, and probably the greatest factor, in controlling yields and quality of wheat in Montana.

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INDEX

Page

Abies—
grandis, undesirability in forest 267
nobilis, growth, a preliminary study 929–934
Abortion—
Contagious. See *Bacterium abortus*.
Bacterin Treatment of Cows having Udders Infected by Bacterium abortus: J. M. Buck and G. T. Creech 663–684
Alcohol, chemical and penetration tests 334, 335
Agars, comparison as media for plating 506–509
Age, Seedlings, Factor in the Resistance of Maize to Sodium Chloride: G. J. Harrison and C. J. King 633–640
Air-pump, use in insect control 1035–1041
Alfalfa—
feeding value, computation 481–482
Hay and Alfalfa Meal, Net-energy Values: E. B. Forbes, J. August Fries, and W. W. Braman 987–995
meal, digestibility 989, 995
Alkali, Tolerance by Maize Seedlings, Weather Conditions a Factor in 638–639
Allard, H. A., and Garner, W. W.: Localization of the Response in Plants to Relative Length of Day and Night 555–566
Allium—
smut infection, relations of species of Urocystis 283–285
species—
experiments with *Urocystis cepulae* 278–282
Susceptibility of, and of Onion Varieties to *Urocystis cepulae*: P. J. Anderson 275–286
Almond, inoculation. *See* Crown gall.
Aluminum, curve of content in sunflower 977–978
Amaranthus retroflexus, mosaic of, cross inoculation 52–55
Ambrosia—
artemisiaefolia, host of cotton stainers 1138
elatior L., wormwood, host of cotton stainer 1138
Ammonia, content of soil and its relations 549–553
Amygdalus—
mira, resistant to crown gall 963, 971
stocks resistant to crown gall, studies 957–971
Anderson, P. J.: Comparative Susceptibility of Onion Varieties and of Species of Allium to *Urocystis cepulae* 275–286
Animal nutrition. *See* Nutrition.
Animals—
Feeding with Trichinous Meat containing Nonviable Trichinae, effects: Benjamin Schwartz 945–947
safety, in use of benzene as larvicide 885–899
Anobium striatum Oliv., endurance of vacuum 1035
Anthracnose, bean, study of resistance 102–145, 149–151, 153
Aphis, carrying of mosaic disease 12, 23, 29
Apple, growth time and features 420–421
Apricot—
and Pear, Fruit-bud Formation Influenced by Certain Environmental and Cultural Conditions: C. B. Wiggans 865–883
fruit buds, differentiation and development 873–877, 879–880
Japanese, high resistance to crown gall 964–968, 970
Archibald, J. G., and Lindsay, J. B.: The Value of Calcium Phosphate as a Supplement to the Ration of Dairy Cows 771–791
Arizona, experiments with date palm 417
Asclepias syriaca, agency in overwintering of mosiac disease 20–32
Ash, percentage in corn 186
Bacillus radiobacter, distinguished from nodule bacteria of legumes by means of litmus milk 997
Back, E. A., and Cotton, R. T.: The Use of Vacuum for Insect Control 1035–1041
Bacteria, cream and whole milk, per cent increase and decrease of counts 696–697, 699

Bacterial—
Page
blight, bean, study of resistance 102–145, 149–151, 153
Count, Whole Milk, Relation to That of the Cream and Skim Milk Separated from It: C. S. Leete 695–699
Flora of Eggs, Effect of Dehydration: George G. De Bord 155–164
spot—
causal organism, morphology, characters, pathogenicity 851–858
control of cowpea 862
control of lima bean 862
cowpea and lima bean, symptoms 842–851
Cowpea and Lima Bean: Max W. Gardner and James B. Kendrick 841–863
relation of parasite to host tissue 858–860
transmission through seed 860–861
wilt, resistance of beans, study 102, 110–145, 151, 153
Bacterium—
abortus, Infection of Cows' Udders, Treatment, Abortion Bacterin: J. M. Buck and G. T. Creech 663–684
flaccumfaciens Hedges, resistance of beans 103, 110–145, 151, 153
phaseoli, resistance of beans 102–145, 149–151, 153
vignae—
bacterial spot, hosts 842, 862
effect of freezing, sunlight, desiccation 855–856
taxonomy 856, 857
viridifaciens, n. sp., identity with *Bacterium vignae*, n. sp. 862
See also Bacterial spot of cowpea and lima bean.
Baking, tests on chloropicrin-treated flours 753–758
Bamboo, temperature interior, note 442
Barber, T. C.: Preliminary Observations on an Insect of the Cotton-Stainer Group New to the United States 1137–1147
Bark, effect on interior temperatures of plants by insulation 449
Barley—
and pea ration, hogs, relation to best dressing percentage 1173–1178
use in combinations for finishing hogs, comparison 1176
Batchelder, C. H.: Fluctuation in the Distribution of the Colorado Potato Beetle 541–547
Bean, Varietal Tests for Disease Resistance: R. D. Rands and Wilbur Brotherton, jr 101–154
Beans—
diseases, resistance tests 102–103
nomenclature discussion 101–102
resistance to bacterial wilt, remarks 151
tests of Lima and other for disease resistance 152
types resistant to blight and anthracnose, descriptions, etc 149–151
Beef—
composition from emaciated cattle with comparisons 1006–1008
Pork and Lamb, Vitamin A in: Ralph Hoagland and George C. Snider 201–221
vitamin A in 207–211, 219
Beetle—
granary, susceptibility to chloropicrin as a disinfectant 745–760
potato. *See* Potato beetle.
striped cucumber, factor in overwintering mosaic 5–6
See also Flour beetle.
Beetles, carrying of mosaic disease 12–18, 30
Beets, effect of diseases on nitrogen in 287
Benzene—
effects in use as larvicide 886–888
grades and prices 888
Larvicide for Screw Worms: D. C. Parman 885–899

Page

Bixby, F. L.: Tests of Deep-well Turbine Pumps ... 227–246
Blight—
bacterial. *See* Bacterial blight.
early, of celery, effect on nitrogen constituents of plant ... 289–291
Blister rust, white pine, longevity of the telicspores and accompanying uredospores ... 901–916
See also Rust.
Bordeaux paste, ineffective against crown gall ... 969, 970
Braman, W. W.—
Cochrane, Donald C., and Fries, J. August: The Maintenance Requirement of Dry Cows ... 1055–1082
Forbes, E. B., and Fries, J. August: Net Energy Values of Alfalfa Hay and Alfalfa Meal ... 987–995
Breeding—
hemp, experiments ... 937–939
livestock ... 377–383
Brewster, Donald R., and Larsen, J. A.: Girdling as a Means of Removing Undesirable Tree Species in the Western White Pine Type ... 267–274
Studies in Western Yellow Pine Nursery Practice ... 1101–1120
Brom-Cresol Purple, Litmus and Janus-Green Milk, Value in a Study of the Nodule Organisms of Leguminosae: J. W. Stevens ... 997–1000
Brotherton, Wilbur, jr., and Rands, R. D.: Bean Varietal Tests for Disease Resistance ... 101–154
Bruce, Donald: Some Possible Errors in the Use of Curves ... 923–928
Bruchus obtectus, Say—
freezing experiments ... 167–179
Insect Affecting Seeds, Effect of Low Temperature on: Walter Carter ... 165–182
temperatures fatal ... 171–181
Buck, J. M., and Creech, G. T.: Abortion-Bacterin Treatment of Cows Having Udders Infected by *Bacterium abortus* ... 663–684
Buds, date palm, offshoot and flowering ... 430
Burgwald, L. H.: Cleaning Milking Machines ... 191–195
Burke, Edmund: The Influence of Nitrate Nitrogen Upon the Protein Content and Yield of Wheat ... 1189–1199
Cabbage, effect of disease on nitrogen in ... 288
Cactus, northern range, determination difficulty ... 431
Calcium Phosphate as a Supplement to the Ration of Dairy Cows, Value of: J. B. Lindsey and J. G. Archibald ... 771–791
Calendra granaria L. *See* Beetle, granary.
California—
fruit-bud differentiation as affected by pruning and irrigation ... 865–883
Indio—
experiments on date palm for minimum temperature of growth ... 402–407
temperatures ... 441–442
Trees, Yield Capacities of the Pure Yellow Pine Type on the East Slope of the Sierra Nevada Mountains: S. B. Show ... 1121–1135
Candy, injury by vacuum in insect experiments ... 1039
Canning, corn, grading of kernels recommended ... 1043, 1046, 1052
Carter, Walter: The Effect of Low Temperatures on *Bruchus obtectus* Say, An Insect Affecting Seed ... 165–182
Cattle—
Emaciated, Chemical Study of Flesh: Ralph Hoagland and Wilmer C. Powick ... 1001–1013
emaciation, discussion of study ... 1010–1013
meat constituents in emaciation ... 1013
Revised Net Energy Values of Feeding Stuffs: E. B. Forbes and Max Kriss ... 1083–1099
Celery—
effect of disease on nitrogen constituents, experimental results, discussion and summary ... 295–300

Celery—Continued Page
Nitrogen Constituents in Plants in Health and Disease: G. H. Coons and L. J. Klotz ... 287–300
Cercospora apii, Fres., cause of early blight in celery and effect, experiments ... 289–292
Cereal products, fumigant for, possibilities and limitations of chloropicrin ... 745–760
Cereals, fumigant for. *See* Chloropicrin.
Chapman, R. N., and Johnson, A. H.: Possibilities and Limitations of Chloropicrin as a Fumigant for Cereal Products ... 745–760
Chemical Study of the Flesh of Emaciated Cattle: Ralph Hoagland and Wilmer C. Powick ... 1001–1013
Chemicals, use in soil disinfection ... 308–321, 329–358
Chicks, Weight, Relationship to Weight of Eggs According to Sex: M. A. Jull and J. P. Quinn ... 223–226
China, source of dried eggs ... 155
Chinch-Bug Attack, Reaction of Certain Grasses: W. P. Hayes and C. O. Johnston ... 575–583
Chloride content, comparison of Egyptian, Sea-Island, and Upland cotton ... 1027–1033
Chlorides, use—
kill trees ... 271, 273
potato-wart control ... 308–321
Chloropicrin—
effects on fumigated cereals ... 749–758
Fumigant for Cereal Products, Possibilities and Limitations of: R. N. Chapman and A. H. Johnson ... 745–760
toxicity—
experiments ... 746–749
insects, summary of literature ... 745, 746
Chromosomes, existence in dioecious plants 941
Citellus—
columbianus columbianus, hibernation ... 761–769
townsendi, hibernation ... 761–769
Citrus groves, spraying with mineral-oil emulsions ... 59–65
Cladosporium spp., relation to tomato leaf mold ... 523–526
Clays, Colloidal, Report on as Emulsifers for Mineral Oils Used in Spraying Citrus Groves: W. W. Yothers and John R. Winston ... 59–65
Cleaning Milking Machines: L. H. Burgwald ... 191–195
Climate—
effect on pine nurseries ... 1101, 1105, 1118
influence upon yields and percentages of nitrogen in grain and straw ... 1196–1198
Climatic conditions, influence upon time of differentiation and rate of development of fruit buds of the pear and apricot ... 865–883
Clover hay, feeding value, computation ... 482–483
See also Sweet clover.
Cochliomyia macellaria Fab., benzene as larvicide for ... 883–888
Cochrane, Donald C., Fries, J. August, and Braman, Winfred W.: The Maintenance Requirement of Dry Cows ... 1055–1082
Colletotrichum lindemuthianum, Sacc. and Magn., B. and C., resistance of beans, study ... 102–145, 149–151, 153
Colloidal clays. *See* Clays.
Colorado Potato Beetle, Distribution Fluctuation: C. H. Batchelder ... 541–547
Contagious abortion, bovine, localization ... 663
See also *Bacterium abortus*.
Coons, G. H., and Klotz, L. J.: The Nitrogen Constituents of Celery Plants in Health and Disease ... 287–300
Copper—
acetate, use to kill trees ... 271–273
compounds, use in potato-wart control ... 308–321
sulphate—
penetration into soils ... 353
use to kill trees ... 271–273
Corn—
and sunflowers, comparison of elements ... 1170–1171
breeding, remarks on ... 98
germination, note ... 1052
growth—
rapidity, comparisons ... 2043–1053
studies of, constants ... 973–98

Page

Corn—Continued
kernel—
Influence of Irrigation Water and Manure on: J. E. Greaves and D. H. Nelson 183–189
Rows, Association with Productiveness and Deleterious Characters: Curtis H. Kyle and Hugo F. Stoneberg 83–99
rows, number, effect of selection on 91, 92
rows, relation to vigor of plant 97–98
kernels—
grading for canning 1043
relation of size and shape to yield 90
Productiveness, Association with Number of Kernel Rows and Deleterious Characters: Curtis H. Kyle and Hugo F. Stoneberg 83–99
seedlings—
Etiolated, Nitrogen Metabolism: S. L. Jodidi 1149–1164
study 1160–1162
selection, use in study of productiveness 91, 92, 93
smut resistance, relation to number of kernel rows 94–97
sweet—
for canning, grading 1043, 1046, 1052
Relation of Size of Kernels to Evenness of Maturity: I. C. Hoffman 1043–1053
two-eared stalks, more numerous from large kernels than from small 1043–1053
use in combinations for finishing hogs, comparison 1176
See also Maize.

Cotton—
R. T. and Back, E. A.: The Use of Vacuum for Insect Control 1035–1041
Stainer Group, Preliminary Observations on an Insect New to the United States: T. C. Barber 1137–1147

Cottons, Egyptian—
and Upland—
leaf-tissue absorption of chlorides and sulphates compared 660
Sulphate Content of the Leaf-tissue Fluids of: J. Arthur Harris, Clara T. Hoffman, and Walter F. Hoffman 653–661
Leaf-Tissue Fluids: J. Arthur Harris, W. F. Hoffman, W. B. Sinclair, A. H. Johnson, and R. D. Evans 1027–1033
physical properties of leaf-tissue fluids 1027–1033

Cowpea—
and Lima Bean, Bacterial Spot of: Max W. Gardner and James B. Kendrick 841–863
bacterial spot, transmission through seed 860

Cows—
average maintenance requirement same as for steers 1081
Dairy, Ration, Value of Calcium Phosphate as a Supplement: J. B. Lindsay and J. G. Archibald 771–791
Dry, Maintenance Requirement: Donald C. Cochrane, J. August Fries, and Winfred W. Braman 1055–1082
fasting, katabolism measure of maintenance requirements 1076–1078
gaseous excreta, determination 1066
increment of heat production due to feed consumption 1075–1076
maintenance, balance of energy 1070–1072
net energy required for maintenance computed to the standard day and uniform live weight 1078
rations—
digestibility 1058, 1059–1062
net-energy value 1074–1075, 1079–81
Treatment with Abortion Bacterin for Udders Infected by *Bacterium abortus*: J. M. Buck and G. T. Creech 663–684

Cream—
and skim milk, bacterial count, relation to bacterial count of whole milk 695–699
centrifugal and gravity separation, bacterial count 695–699

Creech, G. T. and Buck, J. M.: Abortion-bacterin Treatment of Cows having Udders Infected by *Bacterium abortus* 663–684

Page

Cronartium ribicola Fischer, Longevity in 1923 of the Teliospores and Accompanying Uredospores: Perley Spaulding and Annie Rathbun-Gravatt 901–916
Crop Studies, Growth-Equation Constants: W. L. Gaines and W. B. Nevens 973–985
Crops, growth changes numerically expressed by curves 973–985
Crops. *See also* Student's method.
Crown gall, Studies of Resistant Stocks for Prunus: Clayton O. Smith 957–971
Cucumber—
mosaic—
infection with 2–3, 5
of, intertransmission with tobacco 49–52
wild. *See* Wild cucumber.
Cucurbits, mosaic—
infection, trials with infected seed 2–5
of, cross inoculation experiments 42–56
Overwintering and Dissemination: S. P. Doolittle and N. M. Walker 1–58
Curing, ham femur bone, marrow affected chemically 1015–1016
Curves, Errors Possible in Use of: Donald Bruce 923–928
Dactylopius calceolariae Maskell, Identity as Mealybug: Harold Morrison 485–499

Dairy cows—
ration, the value of calcium phosphate as a supplement 771–791
reproduction experiments 787–789
Damping-off, prevention, western yellow pine nurseries 1112
Date palm—
activity in daylight 466
buds, offshoot, and flowering 430
cooling effect of transpiration 431
fruit—
maturing range 415–416
production, note 413
spathe growth 430
growth data available 415–421
Inhibitive Effect of Direct Sunlight on Growth: Silas C. Mason 455–468
leaf—
elongation, time of day for 447
growth under artificial light 460–465, 467–468
moisture requirements 415
range limitation by temperature 450–451
structure and growth 421–430
temperature—
limits of endurance 413
Minimum for Growth and Absence of Resting Period: Silas C. Mason 401–414
temperatures interior—
discussion 446–450
effect of sap currents 443–445
experimental study 431–446
factors governing 431
Thermostasy, Partial of Growth Center: Silas C. Mason 415–453
Dates, notes on importance, antiquity, and climatic requirements 415–416
Davis, R. J.—
and McKinney, H. H.: Influence of Soil Temperature and Moisture on Infection of Young Wheat Plants by *Ophiobolus graminis* 827–840
Studies on *Ophiobolus graminis* Sacc. and the Take-all Disease of Wheat 801–825
Day and Night, Relative Length, Localization of Response in Plants to: W. W. Garner and H. H. Allard 555–566
Daylight, effects on sex in hemp 935, 937, 939, 942
De Bord, George G.: Effect of Dehydration Upon the Bacterial Flora of Eggs 155–164
Dehydration—
Effect on Bacterial Flora of Eggs: George G. De Bord 155–164
egg—
spray process, remarks and experiments 156–159
vacuum process 159–161
Dendrocalamus giganteus, interior temperature, note 442
Digestibility, dry ration for cows, method of approximating 1061–1062, 1081
Diseases, bean, tests of varieties of beans 101–154

Page

Dodge, B. O.: Organization of the Telial Sorus in the Pine Rust, *Gallowaya pinicola* Arth. 641–651

Doolittle, S. P., and Walker, M. N.: Further Studies on the Overwintering and Dissemination of Cucurbit Mosaic. 1–58

Douglas fir, growth. 932–934

Drechsler, Charles: Leaf Spot of Maize Caused by *Ophiobolus heterostrophus*, n. sp., the Ascigerous Stage of a Helminthosporium Exhibiting Bipolar Germination. 701–726

ysdercus obscuratus Distant—
economic importance. 1138–1139
preliminary observations. 1137–1138
habits. 1146–1147
life history, studies. 1139–1146
observations at Brownsville, Tex. 1137
present range in America. 1137–1138

Edelman, David, and Schroeder, W. F.: Composition of Marrow of Fresh and Cured Hams. 1015–1016

Egg albumen, comparison with other media for plating. 500–509

Eggs—
Bacterial Flora, Effect of Dehydration: George G. De Bord. 155–164
dehydration by—
spray process. 156–161
vacuum process. 159–169
differences, fresh and dehydrated. 156
dried, source of supply, China. 155
Hatching Quality in Relation to Shape and Weight: M. A. Jull and S. Haynes. 685–694
storage, effect. 161–163
Weight, Relationship with Weight of Chicks According to Sex: M. A. Jull and J. P. Quinn. 223–226
weights, mean, classified according to incubation results, laid by four groups of Plymouth Rock pullets. 690

Egyptian—
cotton, leaf-tissue fluids, sulphate content of. 653–661
Cottons, Leaf-tissue Fluids: J. Arthur Harris, W. F. Hoffman, W. B. Sinclair, A. H. Johnson, and R. D. Evans. 1027–1033

Electrical conductivity, specific, comparison, in Egyptian, Sea-Island, and Upland cotton. 1027–1033

Emaciation, cattle, chemical study. 1001–1013

Emergence cages, effect on behavior of *Phytophaga destructor* Say. 567–574

Emulsions, spray—
directions for making. 61–65
making and use. 59–65

Endogens—
comparisons of growth with exogens. 420–421
growth center, temperature and control. 447–450

Environmental and Cultural Conditions, Influence on Fruit-bud Formation of Pear and Apricot: C. B. Wiggans. 865–883

Enzymes, proteolytic, in etiolated corn seedlings. 1162

Evans, R. D., Harris, J. Arthur, Hoffman, W. F., Sinclair, W. B., Johnson, A. H.: The Leaf-tissue Fluids of Egyptian Cottons. 1027–1033

Exogens—
comparison of growth with endogens. 420–421
interior heat, observations. 448–449

Fall, best season for sowing silver fir in nursery. 266

Fallow, summer, replacement by field peas in Idaho, note. 1173

Fallowing, effect on yield of wheat. 1194, 1198

Farm animals, maintenance requirements, importance, etc. 1055–1056

Fasting, katabolism, cows, as a measure of the maintenance requirement. 1076–1078

Fat, rancid, use in inactivation of vitamin A. 1017–1026

Fats, melting point and iodine value. 1177–1178

Feed, alfalfa, balance of matter and energy. 990, 991

Feeding—
Page
Animals with Trichinous Meat Containing Nonviable Trichinae, Effects: Benjamin Schwartz. 945–947
stuffs—
alfalfa hay and alfalfa meal, composition. 988
for Cattle, Revised Net-energy Values: E. B. Forbes and Max Kriss. 1083–1099
Improved Method of Computation of Net-energy Values: Max Kriss. 469–484
wheat, nutritive value. 365–375

Feeds—
cattle, net-energy value. 1095–1097
hogs, composition. 1175–1178
net-energy values. 1095–1098

Fertilizer Experiments, Student's Method, Limitation: W. W. Weir. 949–956

Fertilizers, comparative values, measurement, note. 955

Fiber, crude—
in stalk of sunflower and corn, curves. 978–981
seed and ear of sunflower and corn, curves. 983–985

Field-pea Rations, Influence on the Quality of Pork: J. E. Nordby and Robert S Snyder. 1173–1178

Fir—
Noble, a Preliminary Study of the Growth: E. J. Hanzlik. 929–934
Silver—
germination time. 262
Sowing, Best Time in Nursery: J. V. Hofmann. 261–266
White—
stands, yield, comparison with yellow on eastern slopes of Sierra Nevadas in California. 1133–1134
undesirability in forest. 267

Firs, Noble, Silver, and Douglas, Effect of Heat on Seeds, Laboratory Tests: J. V. Hofmann. 197–199

Flour—
beetle, *Tribolium confusum* (Duval), susceptibility to chloropicrin used as a fumigant. 748
disinfection with chloropicrin, results. 752–758

Foliage, transpiration, effect on interior temperatures. 448–450

Food Materials of Wheat Seedlings, Translocation: L. Edwin Yocum. 727–744

Forbes, E. B.—
and Kriss, Max: Revised Net-energy Values of Feeding Stuffs for Cattle. 1083–1099
Fries, J. August, and Braman, W. W.: Net-energy Values of Alfalfa Hay and Alfalfa Meal. 987–995

Forest mensuration, errors in use of curves. 923–928

Forestry—
studies in nursery practice for western yellow pine. 1101–1120
use of graphs and curves, possible errors. 923–928

Forests—
management, killing of undesirable species. 267–274
national, killing undesirable trees, remarks. 268–270

Formaldehyde—
penetration by, chemical tests. 333, 334
penetration of soils. 334–335, 336–337

Freezing, books on, remarks. 165–166

Fries, J. August, Braman, Winfred W., and—
Cochrane, Donald C.: The Maintenance Requirement of Dry Cows. 1055–1082
Forbes, E. B.: Net-energy Values of Alfalfa Hay and Alfalfa Meal. 987–995

Fruit spathe, growth in date palm. 430

Fruit-bud—
differentiation, time as affected by pruning and irrigation. 865–883
Formation—
Pear and Apricot, Influence of Certain Environmental and Cultural Conditions: C. B. Wiggans. 865–883
variation of period. 881

Page

Fuller's earth, emulsifier use 60-61
Fumigant, cereal products, possibilities and limitations of chloropicrin as 745-760
Fungi, damping-off, on western yellow pine 1102-1103, 1108, 1110, 1112
Fungicides, penetration into soils 329-358
Fungus—
cause of tomato leaf mold 523-528
See also *Ophiobolus graminis*.
Fusarium—
lycopersici, study of isoelectric points 386, 393-394, 395-398
oxysporum—
Critical Temperature for Infection of the Potato Seed Piece: H. G. MacMillan and G. A. Meckstroth 917-921
study of isoelectric points 386, 394-398
Gaines, W. L., and Nevens, W. B.: Growth-equation Constants in Crop Studies 973-985
Gallowaya pinicola Arth., Pine Rust, Organization of Telial Sorus in: B. O. Dodge 641-651
Gardner, Max W.—
and Kendrick, James B.: Bacterial Spot of Cowpea and Lima Bean 841-863
Cladosporium Leaf Mold of Tomato: Fruit Invasion and Seed Transmission 519-540
Garner, W. W., and Allard, H. A.: Localization of the Response in Plants to Relative Length of Day and Night 555-566
Gericke, W. F.: Relation Between Certain Heritable Properties of Wheat and Their Capacity to Increase Protein Content of Grain 67-70
Germination—
bipolar, exhibit in Helminthosporium 701-726
cause of change of weight in corn seedlings 1153-1154
early, effect on size of seedlings of western yellow pine 1114, 1116
influence of shade 1111
nursery, western white pine, graphs 893
teliospore, in longevity study 901-908
Western—
White-pine Seed, Methods of Stimulating: J. A. Larsen 889-899
yellow pine, study 1105-1106
wheat—
chemical and physical changes 727-744
Frozen and Nonfrozen, Harvested at Various Stages of Maturity: W. O. Whitcomb and Paul Francis Sharp. 1179-1188
Gibberella saubinetii, study of isoelectric points 386, 390-393, 395-398
Gile, P. L. and Smith, J. G.: Colloidal Silica and the Efficiency of Phosphates. 247-260
Girdling—
Means of Removing Undesirable Tree Species in the Western White-pine Type: Donald R. Brewster and Julius A. Larsen 267-274
methods in killing trees, remarks 268-270
season best for killing trees 274
Grain—
feeding value computation 472-478
protein content, increase by heritable properties of wheat 67-70
Grapes, disease effect on nitrogen in 287
Grasses—
growing of 575-576
Reaction to Chinch-bug Attack: Wm. P. Hayes and C. O. Johnston 575-583
Greaves, J. E., and Nelson, D. H.: The Influence of Irrigation Water and Manure on the Composition of the Corn Kernel 183-189
Growth, tree, errors possible in plotting curves 923-928
Growth-equation Constants in Crop Studies: W. L. Gaines and W. B. Nevens 973-985
Hams, Fresh and Cured, Composition of Marrow: W. F. Schroeder and David Edelman 1015-1016
Hanzlik, E. J.: A Preliminary Study of the Growth of Noble Fir 929-934

Page

Harper, Horace J.: The Ammonia Content of Soil and Its Relation to Total Nitrogen, Nitrates, and Soil Reaction 549-553
Harris, J. Arthur—
Hoffman, Clara T., and Hoffman, Walter F.: Sulphate Content of the Leaf-tissue Fluids of Egyptian and Upland Cotton. 653-661
Hoffman, W. F., Sinclair, W. B., Johnson, A. H., and Evans, R. D.: The Leaf-tissue Fluids of Egyptian Cottons 1027-1033
Harrison, G. J. and King, C. J.: Age of Seedlings as a Factor in the Resistance of Maize to Sodium Chloride 633-640
Hatching, Eggs, Quality in Relation to Their Shape and Weight: M. A. Jull and S. Haynes 685-694
Hay, feeding values, computation 472-478, 481-483
Hayes, Wm. P., and Johnston, C. O.: The Reaction of Certain Grasses to Chinch-bug Attack 575-583
Haynes, S. and Jull, M. A.: Shape and Weight of Eggs in Relation to Their Hatching Quality 685-694
Heat—
Effect on Seeds of Noble and Silver Fir, Western White Pine, and Douglas Fir, Laboratory Tests: J. V. Hofmann 197-199
emission and production in experiments with dry cows 1069
increment, values of feed for, variability of 1090-1093
production—
and increment, alfalfa hay and meal 991-993
correction to a standard day, new method of 1084-1085
cows, dry, increment due to feed consumption 1075-1076
cows, experiments 1072-1074
for cattle, new method of correction to a standard day 1084-1085
increment due to feed consumption 1075-1076
increments per kilogram of dry matter of feed 1088-1090
Helminthosporium turcicum. See *Ophiobolus heterostrophus*.
Hemlock, western—
growth 932-934
undesirability in forest 267
Hemp—
breeding experiments 937-939
intersex types 935-943
seed germination 938, 939
sex—
determination and chromosome segregation 941-942
discussion of genetics 939-942
Genetics: Hugh C. McPhee 935-943
Heterozygosis, livestock, note 377
Hibernation, Ground Squirrels, Observations: William T. Shaw 761-769
Hoagland, Ralph—
and Powick, Wilmer C.: A Chemical Study of the Flesh of Emaciated Cattle 1000-1013
and Snider, George G.: Vitamin A in Beef, Pork, and Lamb 201-221
Hoffman—
Clara T., Hoffman, Walter F., and Harris, J. Arthur: Sulphate Content of the Leaf-tissue Fluids of Egyptian and Upland Cotton 653-661
I. C.: The Relation of Size of Kernels in Sweet Corn to Evenness of Maturity. 1043-1053
Walter F.—
Harris, J. Arthur, and Hoffman, Clara T.: Sulphate Content of the Leaf-tissue Fluids of Egyptian and Upland Cotton 653-661
Sinclair, W. B., Johnson, A. H., Evans, R. D., and Harris, J. Arthur: The Leaf-tissue Fluids of Egyptian Cottons 1027-1033
Hofmann, J. V.—
Laboratory Tests on Effect of Heat on Seeds of Noble and Silver Fir, Western White Pine, and Douglas Fir 197-199

Page

Hofmann, J. V.—Continued.
Sowing, Best Time for Silver Fir in the Nursery ... 261–266
Hogging off field peas, effect on quality of pork ... 1173–1178
Hogs, feeding with peas, results ... 1178–1179
Hominy feed, feeding value computation ... 479–480
Homozygosis, livestock, note ... 377
Hunt, N. Rex, O'Donnell, F. G., and Marshall, Rush P.: Steam and Chemical Soil Disinfection With Special Reference to Potato Wart ... 301–363
Hymenoptera, endurance of vacuum ... 1035
Inactivation of Vitamin A by Rancid Fat: Wilmer C. Powick ... 1017–1026
Inbreeding and Relationship, Approximate Method of Calculating Coefficients From Livestock Pedigrees: Sewall Wright and Hugh C. McPhee ... 377–383
Incubation, results of Plymouth Rock eggs for different weight classes ... 691
Indio, California, air temperatures ... 441–442
Infection ratings, graphs, Goldcoin wheat plants infected with *Ophiobolus graminis* ... 834–837
Insect—
Control, Use of Vacuum: E. A. Back and R. T. Cotton ... 1035–1041
Cotton Stainer Group, New to the United States, Preliminary Observations: T. C. Barber ... 1137–1147
Insecticides. *See* Chloropicrin.
Insects—
carrying of mosaic ... 11–18, 29–30
destruction—
by vacuum tubes ... 1036–1037, 1039
in vacuum vault ... 1038–1039
stage of susceptibility to vacuum ... 1039
Iodine values, pork, indication in field pea ration ... 1177–1178
Irrigation—
effect on—
fruit-bud development of the pear ... 882
soil temperature, note ... 442
influence on fruit-bud formation of pear and apricot ... 878–882
reduction of nitrates in soil ... 1197–1198
relation to wheat protein and yield ... 1198
Water and Manure, Influence on the Corn Kernel: J. E. Greaves and D. H. Nelson ... 183–189
Isoelectric Points for Plant Tissue, Further Studies: William J. Robbins and Irl T. Scott ... 385–399
Jodidi, S. L.: Nitrogen Metabolism in Etiolated Corn Seedlings ... 1149–1164
Johnson, A. H.—
and Chapman, R. N.: Possibilities and Limitations of Chloropicrin as a Fumigant for Cereal Products ... 745–760
Evans, R. D., Harris, J. A., Hoffman, W. F., and Sinclair, W. B.: The Leaf-tissue Fluids of Egyptian Cottons ... 1027–1033
Johnston, C. O., and Hayes, Wm. P.: The Reaction of Certain Grasses to Chinch-bug Attack ... 575–583
Jull, M. A.—
and Haynes, S.: Shape and Weight of Eggs in Relation to Their Hatching Quality ... 683–694
and Quinn, J. P.: The Relationship Between the Weight of Eggs and the Weight of Chicks According to Sex ... 223–226
Kansas, Manhattan, agricultural experiment station, data on grasses under chinch-bug attack ... 580–582
Kaolin—
emulsifier use ... 60
emulsions ... 61, 63, 64
Kendrick, James B., and Gardner, Max W.: Bacterial Spot of Cowpea and Lima Bean ... 841–863
Kernel Rows, Corn, Associations with Productiveness and Deleterious Characters: Curtis H. Kyle and Hugo F. Stoneberg ... 83–99
Kernels, Sweet Corn, Relation of Size to Evenness of Maturity: I. C. Hoffman ... 1043–1053
Kerosene-chemical tests ... 334

Page

King, C. J., and Harrison, G. J.: Age of Seedlings as a Factor in the Resistance of Maize to Sodium Chloride ... 633–640
Klotz, L. J., and Coons, G. H.: The Nitrogen Constituents of Celery Plants in Health and Disease ... 287–300
Kreis test, use in study of vitamin A ... 1018
Kriss, Max—
An Improved Method of Computation of Net-energy Values of Feeding Stuffs ... 469–484
and Forbes, E. B.: Revised Net-energy Values of Feeding Stuffs for Cattle ... 1083–1099
Kyle, Curtis H., and Stoneberg, Hugo F.: Associations Between Number of Kernel Rows, Productiveness, and Deleterious Characters in Corn ... 83–99
Lamb—
Beef and Pork, Vitamin A in: Ralph Hoagland and George C. Snider ... 201–221
vitamin A in ... 215–219, 220
Lard, use in vitamin experiment ... 1017–1026
Larrimer, Walter H.: Behavior of *Phytophaga destructor* Say. Under Conditions Imposed by Emergence Cages ... 567–574
Larsen, J. A.—
and Brewster, Donald R.—
Girdling as a Means of Removing Undesirable Species in the Western White-pine Type ... 267–274
Studies in Western Yellow-pine Nursery Practice ... 1101–1120
Methods of Stimulating Germination of Western White-pine Seed ... 889–899
Larvicide, for Screw Worms, Benzene as: D. C. Parman ... 885–899
Larvicides, toxicity of, chemicals tested ... 885–886
Lassen Forest, yield of yellow pine ... 1125–1126
Lead arsenate, amount on leaves from spraying ... 79, 80
Leaf—
blight differences from leaf spot of maize ... 704, 706–711
spot—
celery, effect on nitrogen constituents, experiments ... 291–294
infection of teosinte ... 712–714
Maize—
Caused by *Ophiobolus heterostrophus*, n. sp., the Ascigerous Stage of a Helminthosporium Exhibiting Bipolar Germination: Charles Drechsler ... 701–726
differences from leaf blight ... 704, 706–711
symptoms ... 701–703
Leaf-Tissue Fluids of Egyptian Cottons: J. Arthur Harris, W. F. Hoffman, W. B. Sinclair, A. H. Johnson, and R. D. Evans ... 1027–1033
Leaves—
date palm—
growth and distribution about axis ... 455
periodicity of elongation ... 456, 457–468
growth in date palm, time of day for ... 447
Leeks, susceptibility to *Urocystis cepulae* ... 275
Leete, C. S.: Relation Between the Bacterial Count of Whole Milk and that of the Cream and Skim Milk Separated from It ... 695–699
Legumes, nodule bacteria studied by means of litmus, brom-cresol purple, and janus-green milk ... 997–1000
Leguminosae, Study of the Nodule Organisms, Value of Litmus, Brom-Cresol Purple, and Janus-Green Milk: J. W. Stevens ... 997–1000
Leptinotarsa decemlineata. *See* Colorado Potato Beetle.
Light, sources and intensity ... 465
Lima Bean and Cowpea, Bacterial Spot of: Max W. Gardner and James B. Kendrick ... 841–863
Lindsey, J. B., and Archibald, J. G.: The Value of Calcium Phosphate as a Supplement to the Ration of Dairy Cows ... 771–791
Litmus—
Brom-Cresol Purple, and Janus-Green Milk, Value in a Study of the Nodule Organisms of Leguminosae: J. W. Stevens ... 997–1

Page

Livestock Pedigrees, Approximate Method of Calculating Coefficients of Inbreeding and Relationship: Sewall Wright and Hugh C. McPhee ... 377-383
Lychnis dioica, sex chromosomes, remarks ... 940-941
Lye, use to kill trees ... 272, 273
MacMillan, H. G., and Meckstroth, G. A.: The Critical Temperature for Infection of the Potato Seed Piece by *Fusarium oxysporum* ... 917-921
Magnesium—
oxide, comparison in sunflower and corn ... 1171
percentage in corn ... 188
Maize—
alkali-resistant strains, breeding methods ... 633-640
Leaf Spot Caused by *Ophiobolus heterostrophus*, n. sp., the Ascigerous Stage of a Helminthosporium Exhibiting Bipolar Germination: Charles Drechsler ... 701-726
Seedlings, Age as a Factor in Resistance to Sodium Chloride: G. J. Harrison and C. J. King ... 633-640
See also Corn.
Malnutrition, cattle, chemical effects, study ... 1000-1013
Malvaceae, hosts of cotton stainer insects, notes ... 1138-1139
Mannite salts, comparison with other media for plating ... 506-509
Manure and Irrigation Water, Influence on the Corn Kernel: J. E. Greaves and D. H. Nelson ... 183-189
Marketing—
fruit, decay caused by Sclerotinia ... 603
vegetables, decay caused by Sclerotinia ... 597-632
Marquis wheat, seeds, use in study of take-all disease ... 801-825
Marrow, Fresh and Cured Hams, Composition: W. F. Schroeder and David Edelman ... 1015-1016
Marshall, Rush P., Hunt, N. Rex, and O'Donnell, F. G.: Steam and Chemical Soil Disinfection with Special Reference to Potato Wart ... 301-363
Martynia louisiana, susceptibility to mosaic disease, and symptoms ... 44-47
Maskell, use of name *Dactylopius calceolariae* ... 485-488
Mason, Silas C.—
Partial Thermostasy of the Growth Center of the Date Palm ... 415-453
The Inhibitive Effect of Direct Sunlight on the Growth of the Date Palm ... 455-468
The Minimum Temperature for Growth of the Date Palm and the Absence of a Resting Period ... 401-414
Maturity, Evenness in Sweet Corn, Relation to Size of Kernels: I. C. Hoffman ... 1043-1053
McKinney, H. H., and Davis, R. J.: Influence of Soil Temperature and Moisture on Infection of Young Wheat Plants by *Ophiobolus graminis* ... 827-840
McPhee, Hugh C.—
and Wright, Sewall: An Approximate Method of Calculating Coefficients of Inbreeding and Relationship from Livestock Pedigrees ... 377-387
The Genetics of Sex in Hemp ... 935-943
Mealybug, *Dactylopius calceolariae* Maskell, Identity: Harold Morrison ... 485-499
Mealybugs, differentiation of species ... 497-499
Meat—
Relation of Protein to Moisture in Conditions of Emaciation ... 1001-1013
Trichinous, Containing Nonviable Trichinae, Feed for Animals, Effect: Benjamin Schwartz ... 945-947
Meckstroth, G. A., and MacMillan, H. G.: The Critical Temperature for Infection of the Potato Seed Piece by *Fusarium oxysporum* ... 917-921
Melting point, pork fat, as affected by a pea ration ... 1175, 1177
Mercuric chloride, penetration of soils ... 337-341

Page

Mercury—
and copper, chemical tests ... 333
penetration—
laterally into soils ... 348-349
upward into soils ... 349-350
use in potato wart control ... 308-321
Metabolism, Nitrogen, in Etiolated Corn Seedlings: S. L. Jodidi ... 1149-1164
Micrampelis lobata, relation to overwintering of mosaic ... 6-13
Microorganisms, Soil, Plate Counts: N. R. Smith and S. Worden ... 501-517
Milk—
effect on nodule bacteria of legumes ... 997-1000
Litmus, Brom-Cresol Purple, and Janus-Green, in a Study of the Nodule Organisms of Leguminosae: J. W. Stevens ... 997-1000
production experiments ... 771-791
Whole, Relation Between Bacterial Count and of the Cream and Skim Milk Separated from it: C. S. Leete ... 695-699
Milking Machines, Cleaning: L. H. Burgwald ... 191-195
Milkweed—
agency in overwintering of mosaic disease ... 20-32
mosaic symptoms ... 27
Miller, Emerson R., and Salmon, W. D.: The Water-Soluble Vitamin Content of the Velvet Bean ... 793-799
Millet, growth test in colloidal silica soil ... 249-254
Mineral—
content of wheat, effects ... 366, 374
ration, dairy cows, effect ... 771-791
Moisture—
Influence upon protein formation in wheat ... 1193-1198
Soil, Influence on Infection of Young Wheat Plants by *Ophiobolus graminis*: H. H. McKinney and R. J. Davis ... 827-840
Mold, Leaf, Cladosporium of Tomato: Fruit Invasion and Seed Transmission: Max W. Gardner ... 519-540
Morphology, Sclerotinia species ... 597-632
Morrison, Harold: Identity of the Mealybug Described as *Dactylopius calceolariae* Maskell ... 485-499
Mosaic—
bean, resistance study ... 112-145, 153
cucumber, infectiousness for pokeweed ... 36
Cucurbit—
cross inoculation experiments ... 42-56
Further Studies on the Overwintering and Dissemination of: S. P. Doolittle and M. N. Walker ... 1-55
publications in study, list ... 57-58
dissemination by seeds of hosts to cultivated cucurbits, experiments ... 58
host plants—
list ... 2-5
relation to overwintering and dissemination ... 55
overwintering on wild host plants ... 55-56
pokeweed, infectious nature and symptoms ... 6-20
spread by striped cucumber beetle ... 34
Muskmelon, infection with mosaic ... 5-6
Neidig, Ray E., and Snyder, Robert S.: Mineral Composition of Sunflowers Grown for Silage ... 1165-1171
Nelson, D. H., and Greaves, J. E.: The Influence of Irrigation Water and Manure on the Composition of the Corn Kernel ... 183-189
Net energy—
maintenance requirement for cattle ... 1093-1094
requirement for maintenance—
and value of the ration ... 1078-1080, 1081
in dry cows ... 1078
value of ration ... 1074-1075
Values—
Alfalfa Hay and Alfalfa Meal: E. B. Forbes, J. August Fries, and W. W. Braman ... 987-995
feeding stuffs, computation, data for, revised methods ... 1086-1088
Feeding Stuffs for Cattle, Revised: E. B. Forbes and Max Kriss ... 1083-1099
revised method of computation ... 1087-1088

Page

Nevens, W. B., and Gaines, W. L.: Growth-equation Constants in Crop Studies ... 973–985
Night and Day. *See* Day and Night.
Nitrate and Nitrogen, Influence Upon the Protein Content and Yield of Wheat: Edmund Burke ... 1189–1199
Nitrates, soil, relation to—
ammonia content of soil ... 549–553
yields and protein content of wheat ... 1193–1196
Nitrogen—
Constituents of Celery Plants in Health and Disease: G. H. Coons and L. J. Klotz ... 287–300
effect of disease of grapes on ... 287
Metabolism in Etiolated Corn Seedlings: S. L. Jodidi ... 1149–1164
Nitrate, Influence Upon the Protein Content and Yield of Wheat: Edmund Burke ... 1189–1199
percentage in corn ... 184–185
study in metabolism, experiments ... 1069–1070
variation in plant substances with disease, etc ... 287–288
water soluble—
distribution in etiolated corn seedlings ... 1157–1160
partition in etiolated corn seedlings ... 1159
Noble fir. *See* Fir; Firs.
Nodule organisms, study by use of milk, litmus, brom-cresol purple, and janus-green ... 997–1000
Nordby, J. E., and Snyder, Robert S.: Influence of Field-pea Rations on the Quality of Pork ... 1173–1178
Nursery Practice, Western Yellow Pine, Studies: Donald R. Brewster and J. A. Larsen ... 1101–1120
Nutrition, effect of sodium variation in a wheat ration ... 365–375
Nutritive Value of Wheat: I.—Effect of Variation of Sodium in a Wheat Ration: George A. Olson and J. L. St. John ... 365–375
O'Donnell, F. G., Marshall, Rush P., and Hunt, N. Rex: Steam and Chemical Soil Disinfection with Special Reference to Potato Wart ... 301–363
Olson, George A., and St. John, J. L.: The Nutritive Value of Wheat: I.—Effect of Variation of Sodium in a Wheat Ration ... 365–375
Onion—
wild, reproduction by bulblet ... 282
Winterbeck, smut infection, experiments 282–283
Onions—
bulblet reproducing, immunity from smut 282
smut—
origin ... 285
susceptibility, conclusions ... 285–286
Susceptibility of Varieties of and of Species of Allium to *Urocystis cepulae:* P. J. Anderson ... 275–286
varieties, experiments for infection with *Urocystis cepulae* ... 276–277
Ophiobolus graminis Sacc.—
and the Take-all Disease of Wheat, Studies: Ray J. Davis ... 801–825
growth and sporulation, effect of light ... 812–813
influence of hydrogen-ion concentration on growth ... 808–812
Influence of Soil Temperature and Moisture on Infection of Young Wheat Plants: H. H. McKinney and R. J. Davis ... 827–840
morphology ... 803–805
overwintering ... 816–818
pathogenicity ... 813–816
Ophiobolus heterostrophus, n. sp.—
ascigerous stage ... 716–721
classification ... 721–725
conidial stage ... 703–705
in The Ascigerous Stage of a Helminthosporium Exhibiting Bipolar Germination, Cause of Leaf Spot of Maize: Charles Drechsler ... 701–726
Ophthalmia, development from rancid lard 1024
Osmotic concentration in terms of freezing-point depression in Egyptian, Sea-island, and Upland cotton ... 1027–1033

Page

Pacific Coast, comparison of regions in study of fruit-bud formation ... 880
Palm. *See* Date palm.
Paraffin oil, interfacial tension in solution ... 76
Parasites, wheat, *Ophiobolus graminis*, influence of soil temperature and moisture ... 827–840
Parman, D. C.: Benzene as a Larvicide for Screw Worms ... 885–899
Pea and barley ration, hogs, relation to best dressing percentage ... 1173–1178
Peach, stocks resistant to crown gall ... 960–969
Pear—
and Apricot, Fruit-bud Formation Influenced by Certain Environmental and Cultural Conditions: C. B. Wiggans ... 865–883
fruit buds, differentiation and development ... 869–873, 878–879
Peas, use in combinations for finishing hogs, comparison ... 1176
Pedigrees, Livestock, Approximate Method of Calculating Coefficients of Inbreeding and Relationship: Sewall Wright and Hugh C. McPhee ... 377–383
Penetration, soil, by fungicides ... 329–357
Pepper, inoculation with mosaic, and symptoms ... 47–49
Pest, control by use of vacuum ... 1035–1041
Phaseolus vulgaris, varietal tests for disease resistance ... 101–154
Phoenix dactylifera—
growth temperature minimum, and absence of resting period ... 401–414
importance ... 415
Phosphate rock, decomposition, effect of colloidal silica ... 254–256
Phosphates—
Efficiency, Relation to Colloidal Silica: P. L. Gile and J. G. Smith ... 247–260
fertilizing efficiency variation with soils ... 247–249
Phosphorus—
pentoxide, corn and sunflower, comparison ... 1171
percentage in corn ... 186–187
Phytolacca decandra, agency in overwintering of mosaic disease ... 32–42
Phytophaga destructor Say, Behavior Under Conditions Imposed by Emergence Cages: Walter H. Larrimer ... 567–574
Pieters, A. J.: Difference of Internode Lengths between, and Effects of Variations in Light Duration Upon, Seedlings of Annual and Biennial White Sweet Clover ... 585–596
Pigweed, mosaic of, cross inoculation with cucumber, and symptoms ... 52–55
Pine—
heights, method of obtaining ... 1122
Pure Yellow Type, Yield Capacities on the East Slope of the Sierra Nevada Mountains in California: S. B. Show ... 1121–1135
rust—
cell fusions, catenulate spores, and intercalary elements ... 643–647
Gallowaya pinicola Arth., Organization of the Telial Sorus: B. O. Dodge ... 641–651
peridial buffer tissue ... 643
seed—
bed, covering depth ... 1102–1108
western white-pine, greenhouse germination ... 896
Seed, Western White-pine, Germination, Methods of Stimulating: J. A. Larsen ... 889–899
western—
White and Noble and Silver Fir and Douglas Fir, Laboratory Tests: J. V. Hofmann ... 197–199
yellow, method of sowing ... 1109, 1110
Yellow, Studies in Nursery Practice: Donald R. Brewster and J. A. Larsen ... 1101–1120
White. *See* White pine.
yellow—
dominant mature heights in virgin forests as indices of site ... 1124–1126, 1135
increment borer used for age determination ... 1131–1133, 1135
new standards of utilization ... 1135

Pine—Continued Page
Yellow—Continued
volume computations, new method 1126–1127, 1135
Pinus—
monticola, methods of stimulating germination of seeds 889–899
ponderosa—
studies in nursery practice 1101–1120
yield capacities of the pure type on the east slope of the Sierra Nevada Mountains in California 1121–1135
Plant—
environment, historical data 585
Tissue, Further Studies on Isoelectric Points: William J. Robbins and Irl T. Scott 385–399
Plants—
Localization of Response to Relative Length of Day and Night: W. W. Garner and H. H. Allard 555–566
temperatures, interior, discussion in article on date palm 401–453
Plum, stocks resistant to crown gall 960–969
Plymouth Rock eggs, relationship of weight and hatching quality 685–694
Poisoning, tree, as method of killing, notes 267
Pokeweed—
agency in overwintering of mosaic disease 32–42
mosaic of, infectious nature and symptoms 34
susceptibility to cucumber mosaic 36
Poplar, temperature, interior, observation 448
Pork—
Beef, and Lamb, Vitamin A in: Ralph Hoagland and George C. Snider 201–221
curing, shrinkage 1176–1178
Quality, Influence of Field-pea Rations: J. E. Nordby and Robert S. Snyder 1173–1178
vitamin A in 211–215, 220
Potassium, percentage in corn 188
Potato—
Beetle, Colorado, Fluctuation in Distribution: C. H. Batchelder 541–547
growth following certain chemical and soil treatments 358–362
Infection of Seed Piece by *Fusarium oxysporum*, Critical Temperature: MacMillan, H. G., and Meckstroth, G. A. 917–921
infestation with Colorado beetle, influence of previous crop 543–547
"volunteer," relation to spread of Colorado beetle 545–547
Wart—
Disinfection of Soil, Chemical and Steam: N. Rex Hunt, F. G. O'Donnell, and Rush P. Marshall 301–303
distribution in United States 302
Potatoes—
commercial varieties, immunity from wart disease 301
disease, effect on nitrogen in 287–288
Potato-tuber tissue, study of isoelectric points 386–389, 395–398
Powick, Wilmer C.—
and Hoagland, Ralph: A Chemical Study of the Flesh of Emaciated Cattle 1000–1013
Inactivation of Vitamin A by Rancid Fat 1017–1026
Protein—
Content—
and Yield of Wheat, Influence of Nitrate Nitrogen: Edmund Burke 1189–1199
wheat, increase 67–70
disintegration in germination of etiolated corn seed 1149–1164
nitrogen, nonprotein, and total nitrogen, proportion in various etiolated corn seedlings 1151–1153
Pruning, influence on fruit-bud formation of pear and apricot 887–882
Prunus—
Stocks Resistant to Crown-gall, Studies: Clayton O. Smith 957–971
umbellata (Black sloe), promising as a rootstock resistant to crown gall 963–864, 970
Pseudococcus spp., descriptions 488–493
Pseudomonas tumefaciens Sm. and T., control as cause of crown gall 957

Pumps— Page
Deep-well Turbine, Tests: F. L. Bixby 227–246
economy of operation, remarks 227–228
turbine, deep-well, form of construction 227
Quinn, J. P., and Jull, M. A.: The Relationship Between the Weight of Eggs and the Weight of Chicks According to Sex 223–226
Ragweed, common, *Ambrosia artemisiaefolia*, host of cotton stainers 1138
Rainfall, western yellow pine nurseries, notes 1118
Ramsey, G. B.: Sclerotinia Species Causing Decay of Vegetables Under Transit and Market Conditions 597–632
Rancidity, studies of vitamin A 1017–1026
Rands, R. D., and Brotherton, Wilbur, jr.: Bean Varietal Tests for Disease-resistance 101–154
Rathbun-Gravatt, Annie, and Spaulding, Perley: Longevity of the Teliospores and Accompanying Uredospores of *Cronartium ribicola* Fischer in 1923 901–916
Ration, Wheat, Effects of Sodium Variation: George A. Olson and J. L. St. John 365–375
Rations—
Field Pea, Influence on the Quality of Pork: J. E. Nordby and Robert S. Snyder 1173–1178
hogs, comparison 1176, 1177
Rats, breeding and testing for vitamin A 202–218
Red clover. *See* Clover.
Respiration, effect on interior temperature of date-palm bud 447, 448
Ribes spp., hosts of *Cronartium ribicola*, experiments 905
Rice, inoculation with *Ophiobolus heterostrophus*, n. sp 714–716
Rio Grande Valley, cotton stainer, preliminary observations 1137–1147
Roaches, endurance of vacuum 1035
Robbins, William J., and Scott, Irl T.: Further Studies on Isoelectric Points for Plant Tissue 385–399
Robinson, R. H.: Spreaders for Spray Materials and the Relation of Surface Tension of Solutions to Their Spreading Qualities 71–81
Rumex acetosa, chromosomes, notes 941
Ruminants, digestion of alfalfa hay and meal 989, 995
Rust—
Pine, *Gallowaya pinicola* Arth., Organization of the Telial Sorus: B. O. Dodge 641–651
See also Blister rust.
Salmon, W. D., and Miller, Emerson R.: The Water-soluble Vitamin Content of the Velvet Bean 793–799
Salt, sodium chloride, use in soil disinfection 317
Sand, quality for tree seed planting 1120
Sap, effect of currents on interior temperatures of plants 443–445, 448, 452
Schroeder, W. F., and Edelman, David: Composition of Marrow of Fresh and Cured Hams 1015–1016
Schwartz, Benjamin: Effects of Feeding Animals With Trichinous Meat Containing Nonviable Trichinae 945–947
Sclerotinia—
economic importance 598–603
germination studies 614–617
infection studies 617–622
intermedia and *S. minor*, morphology, comparison with *S. libertiana* 605, 609, 610
morphology 603–617
ricini, morphology, comparison with *S. intermedia*, *S. minor*, and *S. libertiana* 609–610
Species Causing Decay of Vegetables Under Transit and Market Conditions: G. B. Ramsey 597–632
Scott, Irl, and Robbins, William J.: Further Studies on Isoelectric Points for Plant Tissue 385–399
Screw Worms, Larvicide, Benzene for: D. C. Parman 885–899

Seed— Page
corn, advantage of large kernels 1043–1044
cowpea, transmission of bacterial spot 860–862
germination—
delay in white pine, cause 899
tests, freezing in air and snow 895
selection in control of bacterial spot 862
stratification, western white pine 890–891
tomato, infection with leaf mold, and transmission 534–540
western yellow pine, sowing 1101–1112, 1116, 1117, 1120
wheat, study, review 1179–1180
Seedlings—
corn—
etiolated, acidity of the aqueous extracts 1156–1157
Etiolated, Nitrogen Metabolism: S. L. Jodidi 1149–1164
partition of water-soluble nitrogen 1159–1160
maize, age as a factor in resistance to sodium chloride 633–640
pine, measurements and transplanting data, western yellow pine 1115–1116
transplanting, western yellow pine nurseries 1104
wheat—
chemical and physical changes 727–744
freezing, effects 728, 729
Translocation of the Food Materials: L. Edwin Yocum 727–744
yellow pine, selection for analysis 1122
Seeds—
afterripening and period of rest, tests 897–899
corn, proteolytic enzymes present 1162–1163
date palm, limit of production 450–451
Enemy, *Bruchus obtectus*, Say, Effect of Low Temperatures on: Walter Carter 165–182
Noble and Silver Fir, Western White Pine, and Douglas Fir, Effect of Heat, Laboratory Tests: J. V. Hofmann 197–199
Septoria apii Chester, cause of leaf spot in celery, and effect 289
Sex—
Genetics in Hemp: Hugh C. McPhee 935–943
Relation to Weight of Eggs and Weight of Chicks: M. A. Jull and J. P. Quinn 223–226
Shade—
influence of different degrees on germination in the seed bed, western yellow pine 1113–1115
usefulness in nursery, experiments 1110–1116
Sharp, Paul Francis, and Whitcomb, W. O.: Germination of Frozen and Non-frozen Wheat Harvested at Various Stages of Maturity 1179–1188
Shaw, William T.: Observations on the Hibernation of Ground Squirrels 761–769
Shorthorns, two-line pedigree samples 379–380
Show, S. B.: Yield Capacities of the Pure Yellow Pine Type on the East Slope of the Sierra Nevada Mountains in California 1121–1135
Sida carpinifolia L., natural host of *Dysdercus obscuratus* 1138, 1139, 1141, 1147
Sierra Nevada Mountains, California, Yield Capacities of the Pure Yellow Pine Type on the East Slope: S. B. Show 1121–1135
Silage, Mineral Composition of Sunflowers in: Ray E. Neidig 1165–1171
Silica—
colloidal—
effect on phosphate as millet fertilizer 249–254
effect on rock phosphate decomposition 254–256
Relation to Efficiency of Phosphates: P. L. Gile and J. G. Smith 247–260
gel, relation to phosphate as fertilizer 256–258
Silicon, presence and need in plants 256
Sinclair, W. B., Johnson, A. H., Evans, R. D., Harris, J. Arthur, and Hoffman, W. F.: The Leaf-tissue Fluids of Egyptian Cottons 1027–1033
Silver fir. *See* Fir.
Skim Milk and Cream, Bacterial Count Related to Bacterial Count of the Whole Milk: C. S. Leete 695–699
Smith— Page
Clayton O.: Crown-gall Studies of Resistant Stocks for Prunus 957–971
J. G., and Gile, P. L.: Colloidal Silica and the Efficiency of Phosphates 247–260
N. R., and Worden, S.: Plate Counts of Soil Microorganisms 501517
Smut, onion, study of susceptibility 275–286
Smuts, corn, relation of resistance to number of kernel rows 94–97
Snider, George G., and Hoagland, Ralph: Vitamin A in Beef, Pork, and Lamb 201–221
Snyder, Robert S.—
and Neidig, Ray E.: Mineral Composition of Sunflowers Grown for Silage 1165–1171
and Nordby, J. E.: Influence of Field-pea Rations on the Quality of Pork 1173–1178
Soap emulsions, notes on 59–60
Sodium—
Chloride—
Resistance of Maize Seedlings, Age as a Factor: G. J. Harrison and C. J. King 633–640
use in potato wart control 317
Variation in a Wheat Ration, Effect: George A. Olson and J. L. St. John 365–375
Soil—
Ammonia Content and Its Relation to Total Nitrogen, Nitrates, and Soil Reaction: Horace J. Harper 549–553
Disinfection, Steam and Chemical, with Special Reference to Potato Wart: N. Rex Hunt, F. G. O'Donnell, and Rush P. Marshall 301–363
heterogeneity, Student's method not applicable 949–956
homogeneity, Student's method applicable 949–956
Microorganisms, Plate Counts: N. R. Smith and S. Worden 501–517
Moisture—
and Temperature, Influence on Infection of Young Wheat Plants by *Ophiobolus graminis:* H. H. McKinney and R. J. Davis 827–840
determination 332–333
relation to yields and protein content of wheat 1193–1196, 1198
nitrates, relation to yields and protein content of wheat 1193–1196
particles, relation to penetration of chemicals 345–347
penetration by—
copper sulphate, alcohol, Qua-Sul, formaldehyde, mercuric chloride 335–342, 343–358
fungicides 329–357
relation to experiments made by Student's method 950–955
Temperature and Moisture, Influence on Infection of Young Wheat Plants by *Ophiobolus graminis:* H. H. McKinney and R. J. Davis 827–840
tests. *See* Student's method.
tubes, preparation 331–332
water, effect on soil temperature 442–443, 445–446
Soils—
alkali. *See* Sodium chloride.
disinfection—
by chemical treatment 308–321
by steam-pan treatment 302–308, 321–329
cost 318–321
review of work 301–302
moisture effect on pine nurseries 1101
penetration—
by chemicals 335–338
by fungicides 329–358
by mercury, effect of high water table 347–348
laterally, by mercuric solutions 348–349
percolation by solutions 335–337
relationship to phosphate as fertilizer 247–249
temperature changes under steam pan 321–329
temperatures at Indio, Calif 442–443
Solutions, Surface Tension, Relations to Their Spreading Qualities in Spreaders for Spray Materials: R. H. Robinson 71–81

Page

Sorus, Telial, Organization in the Pine Rust, *Gallowaya pinicola* Arth.: B. O. Dodge 641-651
Sowing, broadcast and with drills, western yellow-pine seed 1103, 1110, 1120
Soy beans, study of isoelectric points 389-390, 395-398
Spaulding, Perley, and Rathbun-Gravatt, Annie: Longevity of the Teliospores and Accompanying Uredospores of *Cronartium ribicola* Fischer in 1923 901-916
Spinach, effect of disease on nitrogen in 288
Spores, leaf spot, difference from leaf-blight spores 704
Spot, bacterial. *See* Bacterial spot.
Spray—
  Materials, Spreaders for, and the Relations of Surface Tension of Solutions to Their Spreading Qualities: R. H. Robinson 71-81
  spreading, publications used in study 81
Spraying—
  effectiveness against potato beetles 545-547
  emulsions for—
    and their making 59-65
    directions 61-65
  Spreading properties, many substances 75
  Squash, infection with mosaic 5
Squirrels, Ground, Observations on the Hibernation of: William T. Shaw 761-769
St. John, J. L., and Olson, George A.: The Nutritive Value of Wheat: I.—Effect of Variation of Sodium in a Wheat Ration 365-375
Stainer, cotton. See *Dysdercus obscuratus* Distant.
Starch, presence in date palm 430
Sterilization—
  soil by steam 318-329
  vibrator 502-504
Sterilizing, methods 191-194
Stevens, J. W.: Value of Litmus, Brom-Cresol Purple, and Janus-Green Milk in a Study of the Nodule Organisms of Leguminosae 997-1000
Stoneberg, Hugo F., and Kyle, Curtis H.: Associations Between Number of Kernel Rows, Productiveness, and Deleterious Characters in Corn 83-99
Storage, effect on eggs 161-163
Student's method—
  application, suggestion 955
  Limitation When Applied to Fertilizer Experiments: W. W. Weir 949-956
Sugar—
  cane, inoculation with *Ophiobolus heterostrophus*, n. sp 714-716
  pine (*Pinus lambertiana*), note 1121
Sulphate content—
  comparison of Egyptian, Sea-Island, and Upland cotton 1027-1033
  Leaf-tissue Fluids of Egyptian and Upland Cotton: J. Arthur Harris, Clara T. Hoffman, and Walter F. Hoffman 653-661
Sulphuric acid, use to prevent damping-off 1112
Sun and air, effect on potato-wart spores 318
Sunflower—
  growth studies of, constants 973-985
  plants, ash 1168, 1169
Sunflowers—
  and corn, percentage composition and pounds of elements removed by crops, comparison 1170
  Mineral Composition When Grown for Silage: Ray E. Neidig and Robert S. Snyder 1165-1171
Sunlight, Direct, Effect on Growth of Date Palm: Silas C. Mason 455-468
Surface tension—
  many substances, tables 74
  of Solutions, Relation to Spreading Qualities in Spreaders for Spray Materials: R. H. Robinson 71-81
Sweet Clover, White, Difference in Internode Lengths Between, and Effect of Light Duration Upon Seedlings: A. J. Pieters 585-596

Page

Synchytrium endobioticum (Schild.) Perc., eradication from infected soil by steam and chemical soil disinfection 301-363
Take-All Disease of Wheat—
  morphology of causal fungus 803-806
  Studies with *Ophiobolus graminis* Sacc.: Ray J. Davis 801-825
Tankage, use in combinations for finishing hogs, comparison 1176
Telial Sorus in the Pine Rust *Gallowaya pinicola* Arth., Organization of: B. O. Dodge 641-651
Teliospores and Accompanying Uredospores of *Cronartium ribicola* Fischer, Longevity in 1923: Perley Spaulding and Annie Rathbun-Gravatt 901-916
Temperature—
  changes occurring in soil under a steam pan in disinfection for potato-wart disease 321-329
  Critical, for Infection of the Potato Seed Piece by *Fusarium oxysporum*: H. G. MacMillan and G. A. Meckstroth 917-921
  effect on Sclerotinia culture and host tissues 604-608, 622-629
  influence—
    in control of growth centers of endogens 447-450
    of growth of *Ophiobolus graminis* Sacc 807-808
  Minimum, for Growth of Date Palm, and Absence of Resting Period (of Date Palm): Silas C. Mason 401-414
  Soil, and Moisture Influence on Infection of Young Wheat Plants by *Ophiobolus graminis*: H. H. McKinney and R. J. Davis 827-840
  study as a factor in infection of the potato-seed piece 917-921
Temperatures—
  date palm, interior—
    comparison with air and soil temperatures 433-446
    discussion 446-450
    effect of sap currents 443-445
    effect of soil water 442-443, 445-446
    factors governing 431
  interior—
    equalization in growth center by tissue insulation 446-447
    plants, discussion 447-450
  limiting effect on date palm growing 450-451
  Low, Effect on *Bruchus obtectus*, Say, an Insect Affecting Seed: Walter Carter 165-182
  soil and air, at Indio, Calif 441-443
Texas—
  cotton stainer, preliminary observations 1137-1147
  San Antonio, experiments on date palm for minimum temperature of growth 408-410
Thermostasy, Partial, of the Growth Center of Date Palm: Silas C. Mason 415-453
Tobacco—
  beetle, control by heat vacuum 1045-1036
  mosaic of, intertransmission with cucumbers 49-52
Tomato—
  Cladosporium Leaf Mold: Fruit Infection and Seed Transmission: Max W. Gardner 519-540
  fruit infection with leaf mold, mode of 530-534
  leaf mold fungus, remarks on 523-528
  seed infection with leaf mold 534-536
  symptoms of infection with Cladosporium leaf mold 519-523
Translocation, of the Food Materials of the Wheat Seedling: L. Edwin Yocum 727-744
Transpiration—
  date palm, relation to interior temperature 431
  foliage, effect on interior temperature 448, 450
Trees—
  growth curves, errors possible in plotting 923-928
  killing—
    by girdling and poisoning, experiments 270-274
    methods, notes 267
  taper curves, possible errors in computing 923-928
  undesirable in forest, two kinds named 267

Page

Trichinae, nonviable—
content of trichinous meat as feed for animals, effect ... 945–947
harmlessness ... 947
Trichinosis, study, review and experiments 945–947
Trichinous Meat, Nonviable Trichinae, Feeding to Animals, Effects: Benjamin Schwartz ... 945–947
Trionymus spp., descriptions ... 494–496
Truck crops, damage done by *Sclerotinia libertiana* Fckl. and related species during transit and storage ... 597–632
Tsuga heterophylla, undesirability ... 267
Udders, Cows, Infection with *Bacterium abortus*, Treatment with Abortion-Bacterin: G. T. Creech and J. M. Buck 663–684
Upland—
cotton, leaf-tissue fluids, sulphate content of ... 653–661
cottons. *See* Cotton.
Uredospores and Teliospores of *Cronartium ribicola* Fischer, Longevity in 1923: Perley Spaulding and Annie Rathbun-Gravatt ... 901–916
Urocystis cepulae—
relation to other species on allium ... 283–285
Susceptibility of Onion Varieties and of Allium Species: P. J. Anderson ... 375–386
Uspulun, use in treatment of corn seedlings for *Rhizopus nigricans* ... 1151
Vacuum, Use for Insect Control: E. A. Back and R. T. Cotton ... 1035–1041
Varietal tests. *See* Bean.
Vegetable drop. *See* Vegetables, decay.
Vegetables, Decay Caused by Sclerotinia under Transit and Market Conditions: G. B. Ramsey ... 597–632
Velvet Bean, Content of Water-soluble Vitamin: W. D. Salmon and Emerson R. Miller ... 793–799
Verbesina encelioides (Cav.) B. and H., host of cotton stainers ... 1138
Vibrator, apparatus for study of bacteria, description and use ... 501–506
Vitamin—
A—
beef, pork, and lamb ... 201–221
effect on growth ... 201
Inactivation by Rancid Fat: Wilmer C. Powick ... 1017–1026
B, quantity in the velvet bean ... 793–799
Water-soluble, Quantity in the Velvet Bean: W. D. Salmon and Emerson R. Miller ... 793–799
Vitamins A and B, effects in wheat rations 367–373
Walker, M. N., and Doolittle, S. P.: Further Studies on the Overwintering and Dissemination of Cucurbit Mosaic ... 1–58
Walnut, temperature interior, observation 449
Wart, potato—
control by salt solutions ... 317–318
Disinfection of Soil for, Steam and Chemical: N. Rex Hunt, F. G. McDonnell, and Rush P. Marshall ... 301–363
Water—
factor in cost of potato wart control ... 321
quality for emulsions ... 59
Watering, western yellow pine, methods in nursery ... 1116–1120
Water-soluble Vitamin Content of the Velvet Bean: W. D. Salmon and Emerson R. Miller ... 793–799
Watery soft rot—
description ... 598–600
spreading ... 614, 615
Weather, conditions a factor in alkali tolerance of maize seedlings ... 638–639
Weight and Shape of Eggs in Relation to Their Hatching Quality: M. A. Jull and S. Haynes ... 685–694
Weir, W. W.: Limitation of Student's Method When Applied to Fertilizer Experiments ... 949–956
Western Yellow Pine Nursery Practice, Studies: Donald R. Brewster and J. A. Larsen ... 1101–1120
Wheat—
age of plants in relation to susceptibility to *Ophiobolus graminis* Sacc. ... 818–820
frosted, germination, change with age ... 1188
Frozen—
and nonfrozen, differences ... 1179
and Nonfrozen, Germination, Harvested at Various Stages of Maturity: W. O. Whitcomb and Paul Francis Sharp ... 1179–1188
germination tests and experiments ... 1183–1188
germination, chemical and physical changes ... 727–744
Heritable Properties, Relation to Their Capacity to Increase Protein Content of Grain: W. F. Gericke ... 67–70
histology of plants in disease caused by *Ophiobolus graminis* Sacc. ... 822–824
mineral content, effects ... 366, 374
Nutritive Value: I.—Effect of Variation of Sodium in a Wheat Ration: George A. Olson and J. L. St. John ... 365–375
parts of plant susceptible to *Ophiobolus graminis* Sacc. ... 820–822
Plants, Young, Influence of Soil Temperature and Moisture on Infection by *Ophiobolus graminis*: H. H. McKinney and R. J. Davis ... 827–840
Protein Content and Yield, Influence of Nitrate Nitrogen: Edmund Burke ... 1189–1199
ration for animals, review of study ... 365–368
seed, testing time ... 1188
Seedling, Translocation of the Food Materials of: L. Edwin Yocum ... 727–744
Studies on *Ophiobolus graminis* Sacc. and the Take-all Disease of Wheat: Ray J. Davis ... 801–825
Whitcomb, W. O., and Sharp, Paul Francis: Germination of Frozen and Nonfrozen Wheat Harvested at Various Stages of Maturity ... 1179–1188
White fir. *See* Fir, Firs.
White pine—
blister rust, longevity of the teliospores and accompanying uredospores ... 901–916
seed germination—
delay, cause ... 899
Methods of Stimulating (Western): J. A. Larsen ... 889–899
Wiggans, C. B.: The Influence of Certain Environmental and Cultural Conditions on Fruit-bud Formation of Pear and Apricot ... 865–883
Wild cucumber, relation to overwintering of mosaic ... 6–13
Wilt, bacterial. *See* Bacterial wilt.
Winston, John R., and Yothers, W. W.: Preliminary Report on Colloidal Clays as Emulsifiers for Mineral Oils Used in Spraying Citrus Groves ... 59–65
Worden, S., and Smith, N. R.: Plate Counts of Soil Micororganisms ... 501–517
Wright, Sewall, and McPhee, Hugh C.: An Approximate Method of Calculating Coefficients of Inbreeding and Relationship from Livestock Pedigrees ... 377–383
Yellow pine—
age of dominants at breast height, curves 1127
site classification ... 1124–1126
Type, Pure, Yield Capacities on the East Slope of the Sierra Nevada Mountains in California: S. B. Show ... 1121–1135
Western, Studies in Nursery Practice: Donald R. Brewster and J. A. Larsen 1101–1120
yield, capacity, factors of conservatism ... 1133
Yocum, L. Edwin: The Translocation of the Food Materials of the Wheat Seedling ... 727–744
Yothers, W. W., and Winston, John R.: Preliminary Report on Colloidal Clays as Emulsifiers for Mineral Oils Used in Spraying Citrus Groves ... 59–65